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Super-Diffraction Limited Measurements Through the Turbulent Atmosphere by Speckle Interferometry

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Speckle interferometric methods provide a means for reconstructing diffraction limited images from atmospherically blurred image data obtained in snapshots with exposure times shorter than the atmospheric redistribution time, typically shorter than 20 milliseconds. This research effort utilized the speckle camera system system operated by Georgia State University at the 1.8-m telescope of the Lowell Observatory (LO) in Flagstaff, Arizona, and the 4-m telescope of the Kitt Peak National Observatory (KPNO) near Tucson, Arizona. The GSU camera was scheduled for approximately ten 6-night runs per year at LO and two 5-night runs per year at KPNO during the term of AFOSR support. Several areas of research were emphasized: (1) Speckle Photometry - The extraction of the differential brightness and color of the components of close binary stars has always been a fundamental limit to the usefulness of these objects to stellar astrophysics. For the first time, simple and fast methods were developed and applied to actual data which would enable the measurement of these parameters for large numbers of stars. Newly

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19. ABSTRACT (Continued)

developed algorithms include a *directed vector-autocorrelation* (DVA) technique for eliminating the 180° deg quadrant ambiguity inherent in speckle interferometric measurements of the astrometry of binary stars. DVA is a simple extension of normal vector-autocorrelation and requires orders of magnitude less computing time that standard image reconstruction methods when applied to binary stars. The second new algorithm is known as the *fork* method and provides a means for a statistically based determination of the intensity ratio of a binary at any selected wavelength, thereby providing color information through the comparison of any two wavelengths. (2) Super Diffraction-Limited Detection – The very high accuracy of speckle astrometry provides a leveraging method for detecting close companions whose spatial separations are far less than the diffraction limit. In principle, this accuracy is sufficient to detect brown dwarf stars and high-mass planets in orbit around one component of a wide binary system. Very large amounts of data pertaining to this problem were collected at LO and analyzed for their limiting astrometric accuracy. The limiting accuracy with the presently available instrumentation would permit the detection of brown dwarfs but is not likely to detect Jovian planets within the sample of some 65 nearby binary systems. Work will continue in this area and will include the development of new filtering and centroiding algorithms to push to higher accuracy. For the first time, a submotion due to the presence of an otherwise unseen companion has been detected by speckle observations in the case of a new star in the system ADS 784. This detection has also been independently confirmed by a submotion in the residuals to spectroscopically obtained radial velocities of the system.
(3) Atmospheric Turbulence Studies – The very extensive data accumulated under this project at the two observing sites now extends over a period of seven years. These data have been analyzed for spatial information and lend themselves to the followup determination of the atmospheric turbulence related parameters r_o, τ_o, and the isoplanatic patch size. A principle difficulty of this analysis has been the removal of local seeing effects produced by dome and other structures, and particularly affected by local thermal sources such as electronic instrumentation, from the intrinsic "seeing" conditions afforded by the atmosphere. A series of measurements obtained outside the dome of the 1.8-m telescope provided an estimate of the mean seeing conditions at the Flagstaff site of 1.2 arcseconds, a quantity equivalent to $r_o \sim 10$ cm.

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FINAL TECHNICAL REPORT

to the

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

for the interval

15 May 86 – 14 November 89

GRANT AFOSR-86-0134

SUPER-DIFFRACTION LIMITED MEASUREMENTS THROUGH THE TURBULENT ATMOSPHERE BY SPECKLE INTERFEROMETRY

Harold A. McAlister
Principal Investigator

Center for High Angular Resolution Astronomy
and
Department of Physics and Astronomy
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22 February 1990

SUPER-DIFFRACTION LIMITED MEASUREMENTS
THROUGH THE TURBULENT ATMOSPHERE
BY SPECKLE INTERFEROMETRY

A. RESEARCH OBJECTIVES

During the interval 15 May 1986 through 14 November 1989, speckle observations with the GSU speckle camera system were obtained at the 1.8-meter Perkins telescope of the Lowell Observatory near Flagstaff, Arizona and at the 4-meter telescope of the Kitt Peak National Observatory near Tucson, Arizona. This Final Technical Report describes the results of an AFOSR sponsored program of research involving the collaborative efforts of astronomers within GSU's Center for High Angular resolution Astronomy (CHARA) and Lowell Observatory Astronomer Dr. Otto G. Franz. This collaboration was directed towards the following scientific problems:

1. Speckle interferometry has been widely applied to the measurement of astrometric parameters of binary stars, i.e., in determining the relative separation and orientation of the components of these objects. Observations accumulated at Kitt Peak and Lowell Observatories were used to determine not only the astrometry of binaries, but were analyzed with a variety of algorithms in order to measure the relative intensity ratios of two stars in a binary system as well. The primary objective here has been to refine the algorithms in order to set up, for the first time, a program in which the differential photometric properties of a large number of binary stars are measurable using speckle interferometric methods. No other means currently exists for routinely determining such properties. Pilot applications of these techniques have been applied to several binary star systems of astrophysical interest.

2. The high accuracy of spatial separation measurements of the components of wide binary star systems by means of speckle interferometry has been used to continue a long-term program with the goal of detecting possible submotions in such systems that might arise from the presence of low-mass planetary or brown-dwarf companions. Sixty-one binary stars with distances less than 25 parsecs from the sun constitute the observing program carried out at nearly monthly intervals at the Perkins telescope. A submotion has been detected from speckle data for the first time in the case of the visual binary star ADS 784.

3. The large amount of data collected in the course of activities described in objec-

tives 1 and 2 provides a unique opportunity to measure the atmospheric properties over northern and southern Arizona. The analysis of these data in order to systematically characterize atmospheric turbulence by measuring the so-called Fried parameter (a measure of the scale size of turbulence cells), the isoplanatic patch size (a measure of the angular extent over which high spatial correlation exists), and the atmospheric redistribution time (a quantity dependent upon the altitude and velocity of the primary layer of turbulence) will continue beyond the term of AFOSR support. Of particular concern has been the difficulty of separating the locally induced turbulence associated with the telescope and dome from that inherent in the atmosphere. The local " seeing" effects may ultimately limit the usefulness of these data for atmospheric turbulence studies.

B. RESEARCH ACCOMPLISHMENTS

1. Observing Opportunities

Observing time on the 1.8-meter telescope was provided by the Lowell Observatory on a guaranteed basis in response to the scientific programs outlined above. Opportunities at the 4-meter telescope on Kitt Peak were provided also on a continuing basis as a result of KPNO's designation of long-term status awarded to a complementary program of binary star astrometry carried out under the sponsorship of the National Science Foundation. We are thus currently guaranteed 4-meter time through the end of 1991. During the interval of this period of AFOSR support, some 35 observing runs totalling more than 150 nights were scheduled on the 1.8-m telescope in Flagstaff. Weather and/or inferior seeing conditions caused a loss of approximately 20% of these nights. Seven runs for a total of 33 nights were scheduled at the 4-m telescope, and only five nights during this time were not useful for observing. These observing opportunities permitted the acquisition of an extraordinary amount of data.

2. The CHARA Image Processing Laboratory

The primary facilities in the CHARA "speckle lab" have been described in the final report to AFOSR Gant 83-0257 and resulted from a grant through the DOD-University Research Instrumentation Program. The hardware consists of a VAX 11/750 computer, with 6 megabytes of core memory and an International Imaging Systems Model 70F image processor connected to the VAX Unibus. This configuration has provided the workhorse capability needed to extract the astrometry from speckle observations of binary stars in

efforts supported by the AFOSR and by the NSF. It has been critically important to the success of all aspects of the GSU/CHARA programs of speckle interferometry. The speckle lab equipment was moved into new quarters adjacent to the astronomy offices in the fall of 1986. The new lab provides an environmentally controlled room for computer hardware and data archival and a spacious area for users. The remodeling of this new laboratory was carried out completely with state funding. For speckle photometry experiments and algorithm development a video digitizing capability was provided with a small grant from the U.S. Naval Observatory through the Office of Naval Research. A commercially available frame grabber board and auxilliary image processing board were purchased along with a Wyse pc-286 computer with 10 megabytes of expanded memory. This new system is allowing us to fully digitize large numbers of speckle frames that can be used for the development of algorithms for reconstructing images of binary stars, and the relatively inexpensive equipment is playing an important role in objective 1 and 3 of this AFOSR sponsored research. The system is being used not only for photometric applications of speckle interferometry, but it is also serving as a potential replacement to the now aging hardwired vector-autorrelator, a one-of-a-kind device that is becoming less competitive with software based processing. A grant from NSF provided for the replacement of the ICCD detector used since 1981 in the speckle camera as well as for an upgrade of CHARA computing facilities. The ICCD is losing gain dramatically through the decay of the microchannel plate intensifier stage, and the strong fixed pattern of the CCD has prevented us from undertaking observations of faint objects. At the time of this writing, the ICCD is being replaced with a PAPA camera built in a collaborative effect with Peter Nisenson of Harvard University. The new detector hardware was delivered to CHARA in February 1990, and is expected to be fully operational by the fall of 1990. In early 1989, several DECstation 3100 workstation type computers were delivered to CHARA and configured via ethernet to provide a significant enhancement of computer power. The new computers are some 20 times faster that the VAX 11/750, and the VAX will be retired (through donation to the Department of Physics, Astronomy and Geology at Valdosta State College) in the spring of 1990.

3. Binary Star Intensity Ratios

New algorithms were developed at CHARA for recovering intensity information from speckle data for binary stars. GSU/CHARA astronomers W.G. Bagnuolo, Jr., J.R. Sowell and graduate students Donald Barry and Brian Mason have optimized various image reconstruction methods for near real-time application with the video digitizing systems. A

first application has been the elimination of the 180° quadrant ambiguity for many speckle binaries, an ambiguity inherent in standard speckle interferometry algorithms. Bagnuolo's new algorithm, known colloquially as the "fork" method, possesses excellent linearity over a wide range of intensity ratios.

The first scientific results forthcoming from the binary star photometry program, an effort for which we have coined the term "speckle photometry", is the determination of the magnitude differences of the stars comprising the system 70 Tauri and Capella. The results as well as analyses of the individual components of the Capella system were published in THE ASTRONOMICAL JOURNAL. Those papers are attached as an appendix to this report.

4. Search for low-Mass Companions to Stars

The very large volume of data that we have accumulated since 1981 at the Perkins telescope continues to be processed by our graduate student Ali Al-Shukri. Al-Shukri the analysis of these data, measuring the autocorrelation functions of the speckle series and has eliminated data obtained during poor seeing conditions from further consideration. The calibration of the Lowell data in a manner which allows their tie-in to the Kitt Peak data was performed. Al-Shukri is expected to publish these results in the form of his Ph.D dissertation prior to June 1990.

The procedure followed has been to determine which data sets have the highest signal-to-noise in their astrometric potential and then to calculate new, accurate visual orbit solutions in order to subtract out those motions. The residuals have then been analyzed for systematic effects indicative of submotions. In general, the results have been negative, i.e. except in the case of ADS 784 we set upper limits to the presence of unseen companions. This result has important consequences on the formation of stellar systems and on the frequency of low mass objects, including brown dwarfs and planets.

The system ADS 784 is a quadruple star system in consisting of a visual binary with a separation of approximately 0.2 arcsec and a period of 83 years. The secondary of this system was known to be a spectroscopic binary having a period just over 4 days. Our data has for some time indicated a sinusoidal set of residuals to the visual orbit, with a period of some 2000 days. Dr. Frank Fekel of Vanderbilt University independently noticed a long-period residual motion in his radial velocity measures of the 4-day system. Through a combined analysis of Dr. Fekel's spectroscopic data and our speckle data, we conclusively detect a fourth component with period of 1700 days. This is the first time that such an object has been found due to submotions in both astrometric (in this case, speckle) and

spectroscopic data.

5. Measurement of Atmospheric Seeing Properties

The newly acquired video digitizing system provided the means for carrying out the proposed methods for measuring three properties of atmospheric seeing: Fried's parameter, isoplanatism, and correlation times. Graduate student Wean Tsay is pursuing the measurement of these properties at Kitt Peak and Anderson Mesa, the site of the Perkins telescope and the proposed site for the CHARA long-baseline telescope array. Tsay spent eight weeks on Anderson Mesa during the spring of 1988 measuring image profiles and motions using a CCD camera on a 14-inch Celestron telescope. These results were analyzed along with micro-thermal data taken simultaneously by Dr. Fred Forbes of the National Optical Astronomy Observatories. A joint paper discussing Anderson Mesa as an interferometer site has resulted from this collaboration and is included in this report.

C. PUBLICATIONS

1. **ICCD Speckle Observations of Binary Stars. I. A Survey for Duplicity Among the Bright Stars.** H.A. McAlister, W.I. Hartkopf, D.J. Hutter, O.G. Franz, and M.M. Shara, THE ASTRONOMICAL JOURNAL, **93**, p. 183, (1987).

2. **ICCD Speckle Observations of Binary Stars. II. Measurements Duirng 1982–1985 from the Kitt Peak 4–m Telescope.** H.A. McAlister, W.I. Hartkopf, D.J. Hutter and O.G. Franz, THE ASTRONOMICAL JOURNAL, **93**, p. 688, (1987).

3. **ICCD Speckle Observations of Binary Stars. III. A Survey for Duplicity Among High Velocity Stars.** P.K. Lu, P. Demarque, W. van Altena, H.A. McAlister, and W.I. Hartkopf, THE ASTRONOMICAL JOURNAL, **94**, p. 1318, (1987).

4. **Gamma Persei–Not Overmassive but Overluminous.** D.M. Popper and H.A. McAlister, THE ASTRONOMICAL JOURNAL, **94**, p. 700, (1987).

5. **ICCD Speckle Observations of Binary Stars. IV. Measurements During 1986 from the Kitt Peak 4–m Telescope.** H.A. McAlister, W.I. Hartkopf, J.R. Sowell, and O.G. Franz, THE ASTRONOMICAL JOURNAL, **97**, p. 510, (1989).

6. **Binary Star Orbits from Speckle Interferometry. I. The Hyades Binary Finsen 342 (70 Tauri)** H.A. McAlister, W.I. Hartkopf, W.G. Bagnuolo, J.R. Sowell, O.G. Franz, and D.S. Evans, THE ASTRONOMICAL JOURNAL, **96**, p. 1431 (1988).

7. **Binary Star Speckle Photometry. I. The Magnitudes and Spectral Types of the Capella Stars** W.G. Bagnuolo and J.R. Sowell, THE ASTRONOMICAL JOURNAL, **96**, p. 1056, (1988).

8. **Seeing Stars with Speckle Interferometry.** H.A. McAlister, AMERICAN SCIENTIST, **76**, p. 167, March-April (1988).

9. **Binary Star Orbits from Speckle Interferometry. II. Combined Visual/ Speckle Orbits of 28 Close Systems.** W.I. Harttkopf, H.A. McAlister, and O.G. Franz, THE ASTRONOMICAL JOURNAL, **98**, p. 1014, (1989).

10. **Binary Star Orbits from Speckle Interferometry. III. The Evolution of the Capella Stars.** W.G. Bagnuolo and W.I. Hartkopf, THE ASTRONOMICAL JOURNAL, **98**, p. 2275, (1989).

11. **ICCD Speckle Observations of Binary Stars. V. Measurements During 1988-1989 from the Kitt Peak and Cerro Tololo 4–m Telescopes.** H.A. McAlister, W.I. Hartkopf, and O.G. Franz, THE ASTRONOMICAL JOURNAL, (to appear in March 1990).

12. **Results in Speckle Photometry.** W.G. Bagnuolo, D.J. Barry, and E.G. Dombrowski, PROCEEDINGS OF THE SPIE, (to appear in 1990).

13. **The CHARA Array. III. Anderson Mesa, Arizona as a Site for an Optical Interferometric Array.** W.S. Tsay, W.G. Bagnuolo, H.A. McAlister, N.M. White, and F.F. Forbes, PUBLICATIONS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC, (to appear in 1990).

D. NEW INVENTIONS OR PATENTS

No new inventions or patents have resulted from this research effort to date.

E. PROFESSIONAL PERSONNEL

The following personnel were directly associated with research effort during the period of this grant. Asterisks indicate those persons who have contributed to this research but whose salaries have not been supported by AFOSR funds.

*Dr. Harold A. McAlister – Principal Investigator, GSU
Dr. Otto G. Franz – Senior Investigator, Lowell Observatory
*Dr. William I. Hartkopf – Senior Research Associate, GSU
*Dr. William G. Bagnuolo, Jr. – Senior Research Associate, GSU
*Dr. James R. Sowell – Research Associate, GSU
*Mr. Ali Al-Shukri – Graduate Research Assistant, GSU
Mr. Wean Shun Tsay – Graduate Research Assistant, GSU
Mr. Edmund G. Dombrowski – Graduate Research Assistant, GSU
*Mr. Donald J. Barry – Graduate Research Assistant, GSU

F. SCIENTIFIC PUBLICATION

The scientific publications listed under section C. above are included on the following to complete this final report.

ICCD SPECKLE OBSERVATIONS OF BINARY STARS. I. A SURVEY FOR DUPLICITY AMONG THE BRIGHT STARS

HAROLD A. MCALISTER,[a] WILLIAM I. HARTKOPF, AND DONALD J. HUTTER[a]
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Received 11 April 1986; revised 21 May 1986

ABSTRACT

A survey of a sample of 672 stars from the Yale *Bright Star Catalogue* has been carried out using speckle interferometry on the 3.6 m Canada-France-Hawaii Telescope in order to establish the binary star frequency within the sample. This effort was motivated by the need for a more observationally determined basis for predicting the frequency of failure of the *Hubble Space Telescope* (HST) fine-guidance sensors to achieve guide-star lock due to duplicity. This survey of 426 dwarfs and 246 evolved stars yielded measurements of 52 newly discovered binaries and 60 previously known binary systems. While the implications for HST operations are described elsewhere, we show that the frequency of close visual binaries in the separation range 0."04–0."25 is 11%, or nearly three-and-one-half times that previously known.

I. INTRODUCTION

The frequency of binary and multiple stars has wide-ranging implications within astrophysics, and even relates to the question of the frequency of life in the universe. The observational limitations of the various techniques for discovering binary stars give rise to selection effects which, if well understood, permit reasonable estimates of the number of overlooked binary stars within a specific sample. For visual binaries, these selection effects are tied to the apparent magnitude of the binary star, the angular separation of the system, and the magnitude difference within the system. In their analysis of the *Index Catalogue of Visual Double Stars* (IDS) (Jeffers, van den Bos, and Greeby 1963), Poveda, Allen, and Parrao (1982) find that after eliminating more than one-fourth of the IDS entries as either optical or spurious pairs, it can be concluded that practically every field star is a potential visual binary. Most of these pairs remain to be discovered.

Speckle interferometry undertaken at the largest telescopes provides an extension of the methods of visual binary star astrometry routinely down to below 0."04 in angular resolution and to magnitude difference as large as 1.5–2.0 mag. Concerted efforts can increase the Δm sensitivity significantly. The accomplishments of binary star speckle interferometry prior to 1984 have been cataloged by McAlister and Hartkopf (1984). These accomplishments include the first direct resolution of some 120 bright binary stars and the accurate measurement of many previously known systems at separations difficult or impossible for other techniques. Although speckle observations have tremendous potential for discovering new pairs, no extensive survey programs exploiting this potential have been undertaken. This has been due to the limited amount of time available on large telescopes to speckle observers and to the obvious priority given to the resolution of known spectroscopic and close visual binaries for stellar mass and luminosity determinations. We report here the first systematic attempt to carry out a speckle interferometric survey for duplicity among a large sample of stars. This survey was motivated by the need for a more directly established estimate of the binary star frequency in the range of separations (0."018–0."20) for which the *Hubble Space Telescope* (HST) fine-guidance sensors would fail to achieve lock. This frequency distribution could potentially lead to significant dead time for HST when all guide-star pairs for a given field contain resolved binaries. The implications of this survey for the HST are discussed elsewhere (Shara *et al.* 1987) and we will restrict our consideration here to the purely astronomical results derived from the observations.

[a] Guest Observer. Canada-France-Hawaii Telescope.

II. SURVEY SAMPLE AND OBSERVATIONAL RESULTS

All of the speckle measurements published prior to this paper as a result of the Georgia State University program have been based upon a photographic speckle camera employing analog techniques for data processing (McAlister 1977). The data for our new survey were obtained using the GSU ICCD speckle camera (McAlister *et al.* 1982, 1987; Hartkopf and McAlister 1986) in which speckle pictures are initially processed digitally with a hardwired vector-autocorrelator and then finally reduced and measured with a VAX 11/750-based image-processing system. The speckle camera has been used regularly at the 4 m KPNO telescope and 1.8 m Perkins telescope at the Lowell Observatory since late 1981. Approximately 2700 measurements of one thousand binary stars, including some 60 newly resolved systems, have been reduced from the data gathered to date, and a detailed discussion of these collected results is to be presented in Paper II of this series. The ICCD data gathered at KPNO between July 1982 and January 1985 were recorded on videocassette tapes and post-processed through the hardwired vector-autocorrelator. The desirability of producing vector-autocorrelograms in real time, and thereby eliminating the effects of tape noise, compressed dynamic range, etc., was realized early on in our experience with the new camera, and provision was made for this in time for the HST-related observations discussed here.

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Following experiments with potential HST guide stars (most with $V = 12$–14) at the 2.5 m Hooker telescope of Mount Wilson and Las Campanas Observatories and the 3.0 m Shane telescope of the Lick Observatory in early 1985, we decided to restrict further speckle observations to bright stars from which we could statistically extrapolate the binary frequency to HST guide stars. Experience to date has shown that speckle observations can resolve systems with combined magnitudes as faint as $V = +15$, but these have invariably been for objects which have *a priori* evidence for duplicity. The speckle measurements of the Pluto-Charon system as recently summarized by Tholen (1985) are a case of particular interest and clearly demonstrate the method's ability to measure faint double objects. Autocorrelograms or power spectra produced from speckle data for faint objects are unavoidably of lower signal-to-noise than those for bright objects and are far more subject to the interpretation of noise fluctuations as features indictive of duplicity. In principle, long integration times and subsequent confirming observations can increase the confidence of a discovery, but both require a significant increase in the investment of telescope time. The reliability of speckle interferometry in discovering faint binary stars thus remains to be established, although we believe that great potential exists in this area. On the other hand, speckle interferometry has now provided the first direct resolution of nearly 200 binary stars (McAlister and Hartkopf 1984; McAlister *et al.* 1987), most of which have been confirmed by subsequent observation. Only a few spurious cases of resolution are indicated by lack of confirmation, and most of these might be the result of closure below resolution limits at the epochs of subsequent observations rather than outright errors in interpreting speckle autocorrelograms.

The sample of stars used in defining the survey was obtained by selecting all stars from the Yale *Bright Star Catalogue* (BSC) (Hoffleit 1982) with equatorial coordinates ranging from 15^h to 23^h in right ascension and $-20°$ to $+60°$ in declination along with a visual-magnitude constraint such that $5.0 < V < 6.5$ (BSC limit). The positional constraints ensured that all objects observed would be within 40° of the zenith of Mauna Kea during the scheduled observing. Complete compensation for atmospheric dispersion using the Risley prisms in the GSU speckle camera requires zenith angles no larger than approximately 60°. The survey-sample results are thus free of dispersion effects that might otherwise mimic duplicity. These criteria resulted in 1191 stars, or 13% of the BSC, as candidate objects for the survey. No selection criteria involving prior knowledge of duplicity were imposed, and all data were reduced blindly with respect to existing visual micrometer or speckle results for any of the visual binary stars that happened to be observed. As will be discussed in Sec. III, we emphasized the observations of dwarf over giant stars in this candidate sample in order to have a distribution of luminosity classes more closely related to that expected for faint HST guide stars.

Speckle observations were obtained on the four nights of 7–10 July 1985 UT using the GSU ICCD speckle camera at the Cassegrain focus of the 3.6 m Canada-France-Hawaii telescope on Mauna Kea. Seeing conditions were generally excellent with FWHM seeing disks estimated to be typically less than 0″.7, occasionally less than 0″.5, and only 2″.0 under the worst seeing conditions encountered during part of the night of 8 July 1985 UT when occasional cirrus clouds appeared. Of particular interest is the atmospheric redistribution or correlation time, found to be comparable to that we have experienced on many nights over the years on Kitt Peak. There was certainly no indication of the very "fast seeing" that is occasionally mentioned for Mauna Kea. Although four nights are certainly insufficient for site comparison, we can unequivocably state that the seeing conditions encountered at the CFH telescope on these four nights were the best we have ever seen anywhere in nearly ten years of speckle observing.

A total of 763 separate objects were observed at the CFH telescope. Seventy-two of these objects were previously known visual or occultation binaries included in the final sample for calibration purposes, as well as a variety of objects in miscellaneous categories. In 13 cases, the primary and secondary components of wide binaries that could not be observed together in our field of 2″.4 square were observed separately to search for close companions. Data for six objects were not included in the final analysis because of instrumental effects or other peculiarities in the autocorrelograms which could not be removed. We thus obtained observations of 672 of the 1191 survey candidates. This represents an inspection of 7.4% of all BSC members for duplicity at a resolution limit of 0″.038, corresponding to the Rayleigh limit of a 3.6 m aperture telescope. All observations consisted of 60 s of video data (equivalent to 1800 individual speckle pictures) taken through a Strömgren y filter and with 10 ms exposure times. Integrated vector-autocorrelograms were stored on floppy disks for subsequent reduction and analysis at GSU in Atlanta. Calibration for scale and position-angle origin was obtained from the measurements of nine visual binaries that have been routinely observed in our program at the KPNO 4 m telescope and were in fact observed on Kitt Peak with the same equipment during a run that ended just five days before the Mauna Kea observing run began. The effect of orbital motion on this calibration is therefore totally insignificant. The spatial calibration procedure employed at KPNO continues to utilize a double-slit mask in the pupil plane as described by McAlister (1977). This method provides a truly external calibration procedure independent of any standard or reference binaries. The scale on the detector for the CFHT data was thus indirectly determined to be 0″.00951 per pixel with an uncertainty indicated by the scatter for the nine calibration stars of approximately $\pm 0.5\%$. The observational results of this survey are presented in Tables I–III.

Table I contains measurements of 52 newly resolved binary stars. The measured angular separation ranged from 0″.040, just above the CFHT diffraction limit, to 0″.965. The mean separation for this sample is 0″.162, reducing to 0″.140 when the two systems with separations exceeding 0″50 are excluded. Since autocorrelated speckle data cannot discern the true quadrant in which the secondary star lies, position angles inherently have a 180° ambiguity. In Table I we adopt $\theta < 180°$. Some of these new binaries have already been confirmed by speckle observations obtained at the KPNO 4 m telescope during November 1985. These confirmed objects are indicated by an asterisk preceding the HR number in Table I. Lack of confirmation at the present time is by no means an indication of decreased confidence in Table I, as only a minority of the new binaries were reobserved in November 1985. The conservative approach we have continued to apply in the inspection of autocorrelograms for duplicity gives us a very high confidence in the reliability of the results in Table I.

TABLE I. Newly resolved systems.

HR	MK	V	Epoch	θ	ρ	d† (pc)	a† (au)	P† (yr)
5612	F6IV	6.65	1985.5171	85°4	0"166	100	17	94
5715	A4V	5.66	1985.5172	155.4	0.217	85	19	78
5818	A2V	5.74R	1985.5172	14.9	0.514	120	61	420
5858	A0V	6.14	1985.5198	98.9	0.130	180	24	91
5895	A3Vn	5.11	1985.5199	25.3	0.126	75	9	26
6123	A5V	5.52R	1985.5200	174.3	0.195	75	15	56
6194	A3IV	6.93	1985.5146	96.3	0.145	250	36	198
6213	F2III	5.92	1985.5173	95.7	0.126	125	16	72
6286	K2III	6.00	1985.5173	121.1	0.292	215	63	360
6317	A7V	6.59	1985.5201	100.6	0.128	100	14	48
6383	A1V	6.46	1985.5173	72.3	0.168	185	32	150
6412	A2V	6.17	1985.5201	70.1	0.136	135	18	72
6571	A2Vn	5.62R	1985.5220	74.0	0.080	105	9	24
6641	A2Vs	6.43	1985.5228	109.0	0.142	160	23	95
6656	A2V	5.02	1985.5228	112.8	0.120	80	9	26
6781	A3V	5.86	1985.5228	173.8	0.106	100	11	32
*6851	B5V	6.30	1985.5231	46.2	0.054	430	24	65
6906	B9V	6.37	1985.5148	100.0	0.118	225	27	110
*6928	B8III-IV	5.73	1985.5148	131.2	0.078	200	16	30
*6941	B2V	6.69	1985.5148	172.8	0.149	1240	186	1165
6956	A4V	6.37	1985.5149	41.4	0.040	125	5	11
*6977	A0Vn	5.78R	1985.5146	31.5	0.151	145	23	85
*6984	B5Vne	6.10	1985.5229	75.8	0.241	395	95	540
6987	F3V	5.45	1985.5148	97.0	0.141	45	7	19
7053	A8Vn	5.14H	1985.5176	66.6	0.184	50	9	30
7091	A1V	6.59R	1985.5175	124.2	0.219	185	41	215
*7109	B8Vnn	6.14	1985.5231	99.3	0.104	250	26	95
7110	A7Vn	6.34	1985.5231	89.6	0.178	90	16	68
7263	F3V	6.23	1985.5233	63.8	0.177	60	11	45
*7272	G1V	6.74	1985.5232	173.0	0.089	40	3	10
7307	B9.5V	5.63	1985.5204	56.2	0.051	145	8	16
7386	F7V	6.19	1985.5233	71.5	0.181	45	8	31
*7436	A3Vn	6.61	1985.5233	173.8	0.137	160	21	95
7480	A3IV	5.67	1985.5149	41.4	0.084	120	10	30
*7554	B2.5IVe	6.51	1985.5149	82.9	0.057	1300	75	300
*7571	A0V+F8IV	6.48	1985.5150	8.9	0.291	200	59	370
*7677	A5Vn	6.45R	1985.5177	55.6	0.050	110	6	12
7684	A2IV	6.01R	1985.5178	23.4	0.340	180	61	420
7752	A1V	6.27	1985.5177	57.1	0.176	165	29	130
*7755	A2Vn	6.31R	1985.5178	13.5	0.176	140	25	110
7767	O9V	5.84	1985.5177	7.7	0.047	1720	80	240
7994	G1V	6.38	1985.5205	2.3	0.169	35	6	20
8246	A0V	5.75	1985.5179	64.2	0.043	145	7	13
8257	F0IV	6.31	1985.5178	110.4	0.184	100	19	90
8274	G9III	6.16	1985.5178	20.2	0.099	200	19	145
8507	F3V	6.39	1985.5208	108.5	0.104	70	7	24
8553	B2V	6.14	1985.5208	60.3	0.185	940	175	1060
8574	B9.5V	5.63	1985.5208	64.1	0.155	140	21	85
8581	F7V	6.14	1985.5151	84.8	0.094	40	3	10
8603	B2Ve	5.73	1985.5182	127.0	0.042	780	33	85
*8617	G2III+A4V	6.40R	1985.5181	115.5	0.113	180	20	85
8690	B3IV:e	5.92	1985.5154	124.0	0.965	650	630	7800

*Confirmed Nov 85 at KPNO 4-m telescope. †Modeled, not observed, parameter.

Table II contains 76 measurements of 74 previously known binary stars. Fourteen of these measurements, indicated by an asterisk preceding the system identification, are for binaries observed for calibration purposes and are not systems that were part of the survey sample. All stars in the survey sample were checked against the Washington Double Star Catalog (WDS) maintained by C. E. Worley at the U.S. Naval Observatory. Three of the survey stars turned out to be binaries previously first resolved by speckle interferometry (HR 6469, 8059, 8704), and three were discovered either by W. S. Finsen or R. H. Wilson using visual interferometry (HR 6676, 7441, 8355). The remaining 66 systems in Table II were all resolved with visual micrometer methods by a variety of observers. The mean separation for the known binaries among the survey sample is 0"504, increasing to 0"562 when the six interferometric pairs are excluded. When compared with the mean separation for the measurements in Table I, the anticipated gain from the increased sensitivity of speckle interferometry to small angular resolutions is clearly seen. As might be expected from our conservative approach to interpreting autocorrelograms, it is mainly the increased resolution rather than a gain in magnitude-difference sensitivity that is responsible for the new binaries in Table I.

Table III contains the HR numbers of 560 stars that were observed in the survey and for which no convincing evidence of duplicity was detected in the autocorrelograms. The effective field of view was determined by the size of the autocorrelator address window and was limited to a rectangle with dimensions 1"22×2"44 centered on the primary star and with the long dimension parallel to a position angle of approximately 30° on the sky. Thus the upper limit to any angular separation that would be detected in the survey was between 0"61 and 1"36 depending upon position angle. A search of the WDS for known binaries in Table III having separations falling within this window was made, and a list of such systems is presented in Table IV. From the comments accompanying Table IV, we can conclude that there is every indication that this survey has completely detected

TABLE II. Measures of previously known systems.

HR/HD/BD	ADS/Disc.	MK	V	Epoch	θ	ρ
*HD 2880	ADS 450 AB	K0V	8.89	1985.5236	149°6	0"125
*HR 142	ADS 490 AB	F8V	5.20	1985.5236	286.9	0.264
*HR 5472	McA 40	G0V	6.05R	1985.5226	79.9	0.061
*HR 5477-8	ADS 9343 AB	A2III	3.86	1985.5145	304.0	0.965
*HR 5504	Fin 309	F7V	6.40	1985.5145	292.0	0.238
*HD 130669	ADS 9397	K2V	8.6	1985.5226	152.2	0.148
HR 5654	Cou 189	M4IIIab	5.89	1985.5171	143.2	0.454
HR 5728	ADS 9617	G3V	6.08H	1985.5171	9.7	0.827
HR 5774	ADS 9688 AB	A5V	5.02	1985.5172	169.2	0.040
HR 5915	ADS 9834	B5V	5.94	1985.5199	122.0	0.556
HR 6255	ADS 10230	A2Vs	5.51	1985.5146	341.6	0.235
HR 6329	ADS 10312 A	A4V	6.33	1985.5201	186.8	1.246
HR 6367	ADS 10355	A1V+F3V	6.06	1985.5201	12.8	0.444
*HR 6377	ADS 10360 AB	A5m	5.39	1985.5228	122.6	0.127
HR 6469	McA 47	F9Vn:	5.51	1985.5228	228.8	0.045
HR 6488	ADS 10531 AB	F8IV	6.49	1985.5228	289.8	0.069
HR 6516	ADS 10598	G9IV-V	5.31	1985.5203	156.9	0.932
HR 6560	Mlr 571	A5V+G5III	6.17	1985.5228	349.0	0.140
*+27 2853	Kui 83 AB	dM0p	9.2	1985.5228	305.0	0.225
HR 6627	ADS 10795	A1V	5.72R	1985.5203	266.4	0.552
HR 6676	Fin 381	F5Vn	6.38	1985.5203	279.3	0.102
*HD 163640	McA 49	A0III	7.4	1985.5229	67.9	0.083
HR 6689	ADS 10912	A3V	5.97	1985.5203	92.7	0.313
HR 6733-4	ADS 11005 AB	F5V	4.78	1985.5204	278.2	1.831
HR 6795	ADS 11111 AB	F2V	5.73	1985.5204	320.2	0.369
HR 6798	ADS 11127	A4V	6.36	1985.5204	193.9	1.261
HR 6803	ADS 11123 AB	B9V+F7III	6.09R	1985.5231	221.8	1.166
HR 6814	ADS 11149 AB	A3V	5.88R	1985.5229	64.1	0.098
HR 6898	ADS 11324	A9III+F6III	6.15	1985.5148	355.2	0.836
HR 6904	ADS 11334 AB	A0V+A4V	6.24R	1985.5229	128.5	0.639
HR 6981	ADS 11483 AB	G2V+G2V	6.21	1985.5148	160.5	1.697
HR 6999	ADS 11520 AB	F9IV	6.49	1985.5149	349.0	0.141
HR 7002	ADS 11524	K1III+M6IIIe	6.4 H	1985.5148	135.9	0.453
HR 7017	Cou 1607	B9V	6.25	1985.5229	115.1	0.175
HR 7033	ADS 11593 Aa	B5V	6.47	1985.5175	303.3	0.145
HR 7048 A	ADS 11640 Aa	A1V+A1V	5.83	1985.5231	129.9	0.141
HR 7048 B	ADS 11640 Bb	A1V+A1V	5.83	1985.5231	139.6	0.137
HR 7090	Hei 72	A1V	6.40R	1985.5176	215.8	0.489
HR 7305	ADS 12239 AB	B8V	6.54	1985.5233	158.1	0.863
*HR 7362	Fin 327	Am	5.03	1985.5231	84.5	0.081
HR 7441	Wrh	A0V+F8III	5.38	1985.5233	266.2	0.053
HR 7486	Kui 93	B5V	6.01	1985.5149	309.1	0.178
HR 7546	ADS 12973 AB	A3V	5.00	1985.5149	177.6	0.180
HR 7599	ADS 13104 AB	F2V	6.51	1985.5149	296.0	0.173
HR 7637	Ho 276	F8V	5.88	1985.5150	295.6	0.233
HR 7657	ADS 13277	F2III	5.22	1985.5177	120.5	0.851
HR 7737	ADS 13572 AB	B9IV-V	6.71	1985.5177	169.7	0.908
HR 7784	ADS 13728 AB	A1V	6.23	1985.5234	108.9	0.329
*HD 195481	ADS 13944 AB	A3V	6.85	1985.5232	213.4	0.058
HR 7840 A	ADS 13946 Aa	B8V	7.11	1985.5205	126.8	0.341
HR 7840 B	ADS 13946 BC	B8V	7.11	1985.5205	295.2	0.108
*HR 7889	ADS 14099 AB	B6III	5.22	1985.5232	111.7	0.345
HR 7958	Kui 101	A3V	6.30	1985.5234	109.6	0.374
*HR 7963	ADS 14296 AB	B5Ve	4.53	1985.5232	15.7	0.793
HR 7982	ADS 14360 AB	F5V+F7V	5.99	1985.5205	12.9	0.982
HR 8038	Kui 102	F1Vp	5.99	1985.5151	52.1	0.296
HR 8056	ADS 14573 AB	F5V	6.25	1985.5151	125.3	1.344
HR 8059	McA 66 Aa	G4III	5.89H	1985.5208	232.6	0.045
HR 8116	ADS 14761	A7Vn	6.27	1985.5150	58.8	0.090
*HR 8123	ADS 14773 AB	F5V+G0V	4.49	1985.5234	13.8	0.202
HR 8258	ADS 15115	A4V	6.11	1985.5178	298.4	0.295
HR 8355	Fin 358	B9V	6.59	1985.5208	91.2	0.093
HR 8355	Fin 358	B9V	6.59	1985.5234	92.7	0.090
HR 8407	ADS 15578 AB	A0IV	5.60	1985.5179	3.4	0.939
HR 8532	ADS 15896 AB	F7V	6.04R	1985.5208	4.1	0.296
HR 8533	ADS 15902 AB	A0V	5.78	1985.5151	217.7	0.121
HR 8545	ADS 15934 AB	G1V	6.35H	1985.5153	340.8	2.495
HR 8612	ADS 16130	G0III+F0V	6.23	1985.5151	136.9	0.136
HR 8629	Kui 114	F6V	6.31	1985.5153	124.9	0.184
HR 8631	ADS 16173 AB	G3V+G8V	5.71	1985.5153	97.7	0.216
HR 8652	ADS 16214 AB	A1V+G:	6.39	1985.5154	306.2	0.492
HR 8704	McA 73	B9III	5.80	1985.5153	284.3	0.073
HR 8704	McA 73	B9III	5.80	1985.5234	283.3	0.074
HR 8708	ADS 16345 AB	A3m+F6V	5.81	1985.5154	210.8	0.910
HR 8737	ADS 16417 AB	G2V+G4V	6.43	1985.5153	345.7	0.290
HR 8739	ADS 16428	A8V+F6V	5.75	1985.5153	306.2	0.563

* indicates those binaries observed but not on survey list

TABLE III. Negative results for bright stars.

HR	MK	V	HR	MK	V
5610	F0V	6.50	6140	G2-6III	5.68
5613	G8III-IV	6.59	6158	B9.5III	5.63
5627	A1V	5.57	6162	A4Vn	5.65
5630	F8V	6.35	6169	A2V	6.41
5635	G7.5IIICN-0.5Fe-1	5.25	6171	K2V	5.75
5640	K1III	5.81	6181	F5IV	6.26R
5648	K0III	6.39	6184	B9.5Vn	5.53
5656	A3Vn	6.08	6185	B9V	5.56H
5659	G5V	6.68	6186	A1Vnn	6.58H
5665	A2V	6.30	6189	F3V	6.35
5676	A2V	5.26	6195	A1V	5.77
5677	M2IIIa	6.13	6201	A7III	6.24
5679	A4V	5.63	6202	F4IV-III	5.57
5692	G8IIIaBa0.3	5.70	6203	A3Vn	6.08
5706	K0V	6.35	6205	F2-4III-IV	5.74
5709	K0III	5.51	6222	F2-3III-IV	5.99
5716	F3-4IVs	6.19	6224	B9.5III	6.03
5717	A0V	6.28	6227	M3IIIab	5.56
5718	B9Vn	5.37	6228	K5III	5.15
5721	F0V	6.12	6230	K4III	6.05
5732	K2III	6.01	6232	A3V	6.10
5734	G1V	6.50	6235	A0Vn	6.03
5740	G0IV-V	6.27	6239	G5III	6.35
5741	K4III	5.46	6240	A5V	6.08
5748	A2IV	6.45	6246	A1V	5.91
5752	AmA3-F0V:	6.15	6248	F1III-IV	6.32
5758	F4Vw	6.57	6256	K0IV	6.13
5760	A4IV	6.46	6258	M1IIIa	5.72
5763	K5III	5.02	6259	K0III	6.13
5764	B2Vn	5.50	6270	K0.5IIIaCa0.5	5.04
5769	F6III	6.38	6277	F0V	6.25
5770	B9V	6.22	6278	A2IV	6.57
5779	F7V	6.51	6279	F0-2V	5.32
5800	M2IIIab	5.11	6280	K2III	5.25
5804	F3V	5.93	6284	K0IV	6.37
5813	F5V:	6.51R	6287	G8III	5.41
5815	F6IV-V	6.50	6292	G5III	6.08
5816	F6V	6.48	6293	K4III	5.35
5817	F4IIIp	6.74	6294	B6V+B7V	6.27
5823	G8III-IV	5.24	6296	G8-K0III-IV	6.19
5830	F2V	5.75	6301	K0V	6.37
5833	B9V	6.00H	6302	F3IV	6.59
5834	B7V	5.07H	6306	M2IIIab	6.62R
5835	G8III	5.84	6307	K0III	6.32
5841	K1III	6.45	6313	K3III	6.34
5853	G5V	5.88	6332	A3IV	5.25
5859	A0V	5.58	6341	A1V	5.93
5870	A3V	5.71	6346	M4IIIab	6.69R
5919	A7Vn	6.29	6349	F8.5IV-V	6.01
5924	M0III	5.44	6351	A5V	6.04R
5927	F7V:	6.37	6361	A9V	6.38
5932	M3IIIBa0.3	5.37	6362	A3IV	6.43
5936	F0IV	5.45	6363	K1III	6.09
5949	A0V	6.31	6372	G5-8IV-V	6.36
5954	F8V	5.47	6376	A2IV	6.28R
5959	A0Vs	5.55	6391	A8V	6.19
5964	F0IV	6.05	6395	B9V	6.29
5968	G2V	5.41	6399	A5III	6.04R
6002	B9.5Vnn	5.78	6406	M5Ib-II	3.48H
6004	A7V	5.63	6407	G5III+F2V	5.39H
6012	F4V	6.47	6414	B5Vnn+B5V	5.88
6013	A0Vnn	6.14	6415	K2III	5.96
6026	B8V+B9VpSi	6.30	6432	A1V	6.00
6033	A4V	5.43	6434	F0-2IV-Vn	6.51
6035	A0V	6.08	6435	A2Vnn	6.02
6036	A1V	6.33R	6443	K0III	5.65
6041	A1V	6.25	6457	A2V	5.12
6050	K4II+F6-8V	5.87	6458	G0V	5.39
6052	F3V	6.50	6467	F4V	6.43
6060	G2Va	5.50	6473	B9Vn	6.21
6061	A0V	6.09	6481	A3V	5.71
6063	G0VCaIIe	5.64	6482	B9V	6.35
6064	G1V	5.66H	6484	A0Vn	5.47H
6067	A9Vn	6.18	6489	F3V	6.44
6074	A3V	5.78	6496	F7V	6.21
6091	F3IV-V	5.49R	6497	B9.5V+G0V	6.06
6096	B9V	6.23	6502	B5V	5.54
6110	A4Vn	6.40	6506	A0V	5.94
6121	G8III	6.11	6507	A8V	5.44
6124	G8III	6.07	6509	A4V	5.80R
6128	M2.5III	5.23	6514	A4V	6.51
6136	K4IIIp	5.39	6533	A1V	5.62R
6137	F2V	6.48	6534	A5V	5.62

TABLE III. (continued)

HR	MK	V	HR	MK	V
6538	G5V	6.56	7057	F0IVv	5.73
6541	F6V	5.64	7059	A2Vm	5.90
6544	B8Vn	5.55	7060	A2IV	6.11R
6548	A2V	5.81	7071	G5III	6.23
6551	A8Vn	6.40R	7073	B6V	6.04
6570	A5V	5.76R	7079	F8V	6.15
6589	A1V	6.34	7080	A2IV	6.52
6592	K1III+F4V	6.36	7081	B3IVp	6.06
6594	F4Vv	5.52	7084	B2.5Ve	5.88
6600	F0V	6.39	7085	A1V	6.25
6601	B1.5V	6.30	7086	A1V	5.88
6609	A1IV-V	6.17	7096	A7III	6.13
6610	A0V	6.56	7098	A0Vs	6.64
6618	A2V	5.75	7100	B3IV	5.91
6626	K3III+F7V	6.68	7102	A3V	5.25
6633	B9.5V	6.22	7115	B6IV	6.09
6642	A1V	6.12	7123	G9IVa	5.51
6655	A9V	5.98R	7126	F4V	5.79
6670	F3-5IV-V	5.77	7131	B2.5V	5.58
6679	A4V	6.52	7132	K4III	5.62
6681	A1V	5.89	7140	G8III+A2	6.02
6684	B2IV-V	5.82	7154	F3III	5.77
6696	A1V	6.36	7162	F9V	5.22
6697	G2V	6.30	7171	B7III-IV	6.50
6720	B8Vne	6.50	7172	F8V	5.23
6732	B9V	6.76	7173	B2Vp	6.75
6741	B3Vn	6.21	7174	B7IV	5.89
6744	A0V	6.50R	7179	B3V	6.22
6753	A2V	6.21	7181	K2III	5.27
6754	F0IV-V	6.34	7183	M3.5IIIab	6.29
6764	F7V	6.52	7185	B5IV	6.41
6775	F7V	5.04	7196	G8III	6.30
6776	A2Vn	6.63	7200	B2IV-V	6.69
6782	A3V	5.90	7202	B5V	5.69
6792	A2V	6.32R	7207	A4V	6.40R
6797	F5V	5.69	7209	A1V	5.42
6806	K2V	6.40	7214	A4V	5.83
6830	A4V	6.36	7215	A7V	5.01
6831	F8V	6.56	7231	F1V	6.53
6843	A8V	6.31	7251	A0Vn	5.38
6844	F2V	6.63	7258	B3V	6.49
6847	G2V	6.29	7260	G5V	6.07
6849	F1V	6.37	7261	F0V	5.23
6852	B9V	5.99R	7267	F5IV-V	6.48
6873	B3Ve	6.13	7269	B5Vn	6.34
6877	A7V	5.12	7279	B3V	5.34
6878	B9.5V	6.33	7284	A3V	6.18
6881	B8IV-Ve	5.73	7286	A2Vn	5.93R
6883	A2V	6.00R	7288	A3V	6.49
6885	K3III	5.25	7293	G4V	6.75
6890	F6III-IV	6.38	7294	G4V	6.57
6900	B9V	6.74	7301	A4V	5.64
6902	G8III-IV+A0V	5.65	7313	A1Vn	6.19
6918	G0III+A6V	5.21	7324	A3V	6.68
6919	B8V	6.20	7332	A2V	6.02
6924	B3V	6.53	7345	G8V	6.31
6925	K3III	6.07	7346	B9V	6.31
6935	K0III	5.39	7351	A1V	6.26
6944	A0Vn	5.14	7364	B9.5V	6.40
6946	B2V	5.72	7368	G8V	6.37
6955	A2V	5.77	7384	A0V	6.31
6957	A4III	5.94	7390	A0V	5.63
6962	A2V	5.76	7403	B3Ve	6.34
6967	B8IIIpSiSr:	6.42	7457	B8Vne	6.05
6970	G8III	5.14	7466	B5V	6.43
6971	B4Ve	6.59	7476	K2III+F8V	6.2
6974	B9.5V	6.56	7516	B3III	6.48
6975	A3V	6.46R	7519	A3IV	5.91
6976	A1V	6.40R	7541	K5III	6.04
6985	F5III	5.39	7553	F0V	5.39
6992	B9V	6.42R	7559	K5III	6.13
6995	G8IV	6.29	7569	G0V	6.13
7000	F1IV-V	6.66	7572	B7V	6.54
7003	F0V	6.26R	7580	B9.5Vn	6.53
7010	G8III	6.28	7593	B7Vn	5.71
7030	B8V	6.41	7594	B8V	6.49
7034	F7V	6.31	7596	A0III	5.61
7040	B9V	5.02	7598	A2V	6.15
7044	F1III-IV	5.70	7610	A1IV	5.28
7047	F6V	6.31	7622	B9III	5.33
7051	A4V	5.06H	7636	G8III	6.17
7052	F1V	6.02H	7649	A3V	5.71
7054	F0Vn	5.37H	7655	K0III	6.20

TABLE III. (continued)

HR	MK	V	HR	MK	V
7656	B4V	5.88	8166	G8IV	5.68
7670	G6IV+M6V	5.71	8169	A1V	6.04
7672	G1V	5.80	8170	F8V	6.40
7675	A1Vn	6.55	8178	A3V	5.16
7683	G5IV	6.17	8182	K1III	6.05
7687	M1IIIa	6.14	8186	A1V	6.63
7688	B3V	5.07	8187	F1V	5.49
7689	K0IV	5.36	8190	F1IV	5.71
7693	F3V	6.43	8194	A2V	6.15
7697	F5V	5.85	8197	K0III	6.32
7700	B3V	6.31	8198	A8III	5.68
7705	F5IV	6.48	8205	F5V	6.13
7709	B1V	6.49	8212	F3V	6.61
7711	A3III	5.52	8215	B3V	5.31
7715	F7V	5.85	8217	A1V	5.41
7719	B7Ve	5.92	8220	F0V	5.80
7721	B7V	6.92	8222	F0V	6.57
7731	A7IVn	5.18	8231	B9.5V	6.08
7733	K4III	6.14	8250	F7V	6.47
7734	A0V	6.45	8261	G8III-IV	6.36R
7743	K0III	5.66	8263	A2V	6.25
7746	K1III	6.13	8265	A2V	6.18
7753	G8III	5.32	8266	A5V	5.01
7756	F5V:	5.91	8267	F1IV	5.45
7757	B6III	6.48	8270	A9IV-Vn	5.67
7760	G9III	6.22	8272	A7III	6.20
7769	A2V	5.58	8276	F2V	5.85
7777	B2V	6.45	8283	G1V+G0V	5.18
7782	A0III	6.57	8302	F0V	5.99
7793	F8V	6.17	8307	A0V	5.65R
7803	B9V	6.15	8310	G2V	6.08H
7807	B2Ven	5.90	8314	G0V	5.94
7821	B9V	6.13	8319	A1V	5.58
7829	A7V	6.74	8328	A1V	5.64
7830	A3Vn	5.94	8330	F3V	6.21
7855	F6V	6.13	8332	A7V	6.17
7857	A2Vnn	6.56	8338	B8V	6.12
7865	A7V	6.19	8341	B2V	6.29
7880	B9V	5.59	8343	A1Vs	5.04
7883	A2V	5.43	8354	F6IV-Vvv	5.53
7887	F0V	6.49	8356	B3Ve	5.08
7899	B3V	5.96R	8358	A0Vs	5.68
7914	G5V	6.45	8372	K5V	6.38
7917	A2V	6.08R	8373	A2Vnn	5.54
7927	B2IV-Ve	6.66	8382	K2V	6.22
7947	F7V	5.14	8391	F5III	6.40R
7953	A0V	5.58	8396	A2V+K0III	6.37
7954	A0Vn	6.40	8403	B5III	5.78
7973	F5V	5.98	8404	B9.5V	5.80
7974	A1Vs	6.33	8406	O9V	5.56
7981	A1Vs	6.52R	8415	K2III	5.78
7983	B4Ve	6.33	8419	B9Vn	5.63R
8004	A1V	6.66	8421	M4IIIab	6.13
8006	A9Vn	6.55	8422	A0V	6.44
8009	B8Vnne	6.70	8424	K5III	5.14
8012	A4V	5.58R	8427	B2V	6.27
8014	B8Vn	6.57	8429	A3V	6.19
8023	O6Ve	5.96	8434	A0III	6.39
8041	G1V	6.21	8438	B7Vne	5.78
8044	M3IIab	5.65	8441	F1IV	6.11
8054	B6V	6.50	8442	G6III	6.32
8057	M1III	6.31	8445	K5III	6.42R
8058	A3V	7.31H	8448	G2IV+K0III	6.11
8066	K5III	5.61	8451	A1Vnn	6.27
8077	F8V	5.94	8455	G0V	6.18
8083	A0V	6.17	8459	A3III	6.46
8085	K5V	5.21	8460	A8IV	6.32
8086	K7V	6.03	8462	F2V	6.03
8088	K2IV	6.42R	8463	A5V	5.40
8090	K5III	6.15	8467	F7V	6.39
8094	B9V	5.59	8472	F8V	5.24
8095	F5IV	6.45	8476	K0III	6.30
8098	A2Vs	6.07	8482	K2III	5.89
8101	A1V	6.68	8487	A0III	5.53
8105	B1Vp	6.54	8489	A2Vnn	5.68R
8121	M1III	6.38	8491	A1Vn	6.21
8134	A2V	6.40	8495	A5Vn	6.15
8139	F2V	7.05	8503	G9III	6.37
8141	B5V	5.82	8506	G8III	5.88
8144	B7Vn	6.19	8510	A9IIIp	6.17
8149	K5III	5.96	8512	B8IIIpHn:Hg:	5.37
8158	B6IV	6.29	8513	B5IV	5.37
8165	K1III	5.57	8514	F6V	6.17

TABLE III. (continued)

HR	MK	V	HR	MK	V
8520	B2IV-Ve	5.01	8654	K5III+K2III	5.95
8528	B5V	6.41	8656	K0III	5.08
8530	G6IIIBaII	5.93	8666	F0III-IV	5.76
8534	G6.5III	5.76	8670	G7III	5.26
8535	B8III-IV	6.16	8673	A0V	5.66
8548	F7V	5.75	8676	A9III-IV	6.19
8549	B2V	6.46	8677	B9.5IV	6.36
8554	B5III	6.57	8681	F0IV-V	6.54
8562	K5IIIa	5.58	8682	B5Vne	6.12
8565	F3IV	6.40	8688	K1III	5.43
8567	B8Vs	6.37	8697	F7IV	5.16
8569	A2V	6.56	8705	B8V	6.46
8575	K2III	6.40	8706	B7III-IV	6.34
8583	A8III	6.38	8710	K3III	6.19
8586	F1V	6.24R	8711	K2.5IIIb	5.56
8588	A6V	5.79R	8712	K0III	5.81
8589	G8III	6.35R	8715	A7III	6.11
8594	G8III-IV	5.71	8716	K0III-IV	5.72
8605	A1III	6.40	8723	B7III	5.74
8606	B3V	6.29	8724	A3Vs	6.51
8607	A3V	6.38	8725	B2IV	5.59
8610	K2III	5.03	8727	G9III	6.31
8621	M4III	5.21R	8729	G2.5IVa	5.49
8624	A2V	6.21R	8730	K1III	6.28
8633	K0III	5.93	8731	B4IIIep	5.43
8640	B2III	5.25	8733	B2IV-V	6.18
8643	G9III	5.94R	8734	G8IV	6.16
8645	A5V	6.45	8735	F0-2V	5.37
8647	A0Vn	6.41	8738	A1V	6.33
8651	B1V	6.43	8741	K5III	6.07
8653	G8IV	6.51	8745	B9III	6.43

those previously known visual binaries having geometries and magnitude differences falling within the survey window of resolution. Previously known systems that were missed by the survey can be invariably excused on the basis of their currently exhibiting unresolvable separations and/or possessing very large magnitude differences.

III. DISCUSSION

The limiting resolution of speckle interferometry when carried out at 4 m class telescopes permits the detection of binary star systems that would otherwise by overlooked by traditional visual micrometry surveys using large refractors or even by attempts to detect variable radial velocity. Although the direct resolution of spectroscopic binaries continues to be a major justification for binary star speckle interferometry, the great majority of radial-velocity amplitudes that have and can be measured lead to semimajor axes too small to encourage direct resolution. This situation could be improved substantially if precision radial-velocity methods, such as those summarized by Campbell and Walker (1985),

TABLE IV. K[illegible] visual binaries not resolved in survey.

HR	ADS	Disc.	Epoch	Comment*
6388	-	McA	1985.5174	1
6484	10526	McA Ap	1985.5227	2
6697	-	McA	1985.5228	3
6918	11353	Stf 2316 Ap	1985.5148	4
7059	11667	McA Ap	1985.5231	5
7209	-	A 3195	1985.5204	6
7466	12696	WRH 23 Ap	1985.5234	7
7953	14293	Bu 65	1985.5206	8

*Comments - Unreferenced dates of speckle observations refer to the catalog of McAlister and Hartkopf (1984):

1. Unresolved at 10 epochs between 1977.49 and 1981.47 with separation of $0\farcs039$ on 1980.48.
2. A companion with a separation of $0\farcs29$ seen only on 1981.47; unresolved on 1985.25 by Bonneau et al (1985)
3. Rapidly moving pair closing from $0\farcs114$ to $0\farcs065$ between 1981.5 and 1984.3.
4. A companion with a separation of $0\farcs25$ seen only on 1976.61; unresolved at four other epochs between 1976.3 and 1979.5.
5. A companion with a separation of $0\farcs13$ seen only on 1980.48; unresolved on 1976.30.
6. Consistently unresolved at five epochs between 1977.48 and 1981.47.
7. Consistently unresolved at eight epochs between 1976.45 and 1981.70.
8. This system with an estimated Δm of 3.6 magnitudes is probably also showing a separation just outside the survey window.

were routinely applied to long-period binary systems. Thus speckle interferometry using large reflectors can realistically be considered as a technique that begins to bridge the gap between classical visual and spectroscopic detection of binary stars and provides important overlaps into the regimes of these two complementary methods. Among the 52 newly resolved binaries in Table I, there are 13 which are designated as spectroscopic binaries by the BSC. The longest spectroscopic orbital period in this subgroup is just over 13 days, and it can be concluded that none of the newly resolved systems can be associated with previously known spectroscopic orbits. There are ten stars in Table I for which the BSC designates the radial velocity as being variable and nine additional stars with suspected variable velocities. Whether or not these velocity variations can be attributed to the speckle companions remains to be established. Two of the stars in Table I show composite spectra: HR 7571, A0 V + F8 IV, and HR 8617, G2 III + A4 V, and it is likely that these spectral types correspond to the individual components now resolved by speckle interferometry. It is also interesting to note that we have discovered a new close companion to component C of the famous visual multiple system ϵ Lyrae (HR 7053).

A few of the stars we have observed have been included in other surveys for the purpose of estimating duplicity frequencies. In their study of solar-type dwarfs, Abt and Levy (1976) found a constant radial velocity for HR 6987, a star which we find to be double with a separation of 0"141. We estimate that HR 6987 would have a period of the order of 15 yr, with a maximum possible radial-velocity variation of approximately 10 km/s, a value that would be decreased according to the actual orbital inclination. The long period and likely small velocity amplitude are not inconsistent with the conclusion of Abt and Levy (1976). Three stars for which we failed to detect companions but for which Abt and Levy (1976) determined spectroscopic orbits are HR 5954 ($P = 3100$ days), HR 7261 ($P = 49.1$ days) and HR 8283 ($P = 13.2$ days). In the case of HR 5954, the 8.4 yr period system could conceivably be resolvable by speckle interferometry at maximum angular separation, provided that the magnitude difference is not too large for this single-lined system. The shorter periods for HR 7261 and HR 8283 give no hope for direct resolution by single-aperture interferometric techniques. In nine other cases (HR 5968, 6091, 6458, 6594, 6775, 7172, 7947, 8472, 8697), Abt and Levy (1976) found constant velocities for stars which we also see as single while they suspect variable velocity for HR 6985, a star that is unresolved to us. The only star we have in common with the study of B type dwarfs by Abt and Levy (1978) is HR 8520, an object for which neither spectroscopic nor speckle analysis find evidence of duplicity. The observational selection effects of spectroscopic methods and speckle methods do overlap some in their sensitivity to binary star discoveries, but in the case of bright-star duplicity surveys the two approaches serve primarily as complementary rather than redundant means for discovery.

The complementary nature of speckle interferometry with spectroscopic and visual surveys for duplicity is exemplified in the case of the B stars. Abt (1983) discusses the duplicity frequency for a sample of 114 B2–B5 dwarfs, pointing out an absence of such binaries with periods between approximately 1/3 yr and 270 yr. Our Table I includes two stars in this spectral range that have estimated periods of less than 100 yr and three more stars with periods less than 1000 yr. Even these few binaries in this period range would significantly alter the depression in the frequency distribution for B stars shown in Fig. 2 of Abt (1983).

Heintz (1978) defines an index $C = 0.22\Delta m - \log \rho$ as a "measure of difficulty" for visual detections based upon magnitude difference and angular separation. He states that for stars brighter than magnitude 9.5 binaries for which $C < 0.5$ have been completely detected by surveys, while those for which $C > 1.0$ are "virtually unknown." In the separation range of 0"038 to 0"25, in which 47 of the 52 newly resolved binaries fall, the value of C ranges from 1.4 to 0.6 if we assume that the average Δm within this sample is approximately 0.5 mag. The majority of these new binaries thus have very small likelihood of ever contributing to duplicity surveys employing visual methods.

We can conclude that the great majority of the binaries newly resolved in this survey fall into an orbital-period regime not generally detectable by other methods and have thus not contributed to previous studies of the stellar duplicity frequency. Furthermore, these systems would not be discovered if this same sample were to be surveyed by classical spectroscopic and visual methods. If we estimate that the 47 new systems in Table I with separation less than 0"25 are uniquely discoverable by speckle interferometry at large telescopes, then we can conclude that duplicity surveys in the past have typically overlooked at least approximately 7% of the actual binaries because they fall into the selection regime between spectroscopic and visual methods. This addition to the overall frequency of binary stars must be considered a minimum value to the true increase because speckle interferometry does not completely bridge the gap between spectroscopy and micrometry. Although this survey is not intended to provide the means for independently modifying across all spectral types the binary frequencies that have been summarized by Abt (1983), the breakdown in frequency as shown in Table V offers comparisons supportive of the high frequency of duplicity and its variation with spectral type.

Our sample of 672 bright stars is not generally representative of the luminosity-class makeup of the BSC because this observed sample includes 424 dwarfs and 246 stars of luminosity class IV or brighter as indicated in Table V. Two stars,

TABLE V Summary of duplicity results by primary spectral type (no. of stars observed/no. of stars resolved/% resolved).

Spectral Type	Luminosity Class V	IV	III	II
O	3/ 1/33	-	-	-
B	104/17/16	18/ 3/17	15/ 2/13	-
A	193/45/23	18/ 4/22	21/ 1/ 5	-
F	87/16/18	28/ 4/14	13/ 2/15	-
G	31/ 7/23	12/ 1/ 8	38/ 4/11	-
K	8/ 0/ 0	4/ 0/ 0	59/ 2/ 3	1/ 0/ 0
M	-	-	17/ 1/ 6	1/ 0/ 0
All	426/86/20	80/12/15	163/12/ 7	2/ 0/ 0

HR 7048 and HR 7840, contribute two systems each to Table II, but the primary spectral types are included only once each in Table V. Thus there were 670 different primary spectral types available for the 672 stars observed. Dwarf primaries accounted for 63.5% of the survey sample, whereas dwarfs comprise approximately one-third of the complete BSC. Our selection of dwarfs over giants was based upon the need to extrapolate to the apparent-magnitude range ($V = 9.0$–14.5) characteristic of HST guide stars in which dwarfs dominate over giants. For the 424 luminosity class V stars in our sample, 86 were found to be double with an overall frequency of occurrence of 20%. Forty of these dwarf binaries are newly discovered. There were 164 luminosity class III stars observed, of which 12, or 7%, were found to be double. Five of the giant binaries are newly resolved. It is interesting to note that the fraction of observed binaries previously unknown is similar across all luminosity types and confirms the anticipated decrease in detected duplicity rate for evolved stars, owing to significant increases in magnitude difference when one star leaves its companion behind on the main sequence. The 9.4% increase in the overall frequency of dwarf binaries found for the survey sample leads to the prediction that another 250 binary stars would be discovered in a complete speckle interferometric survey of BSC dwarfs. Our results would also imply the existence of an equal number of newly resolvable giants and subgiants. This is a substantial increase in the incidence of close visual binaries among the bright stars. Discovery and continued speckle measurement of these objects would eventually result in a significant increase in the number of binary stars for which fundamental determinations of masses and luminosities can be made. The routine observation of these stars by modern programs of high-accuracy radial-velocity measurement is extremely important to this potentially rich harvest.

Estimates of the orbital periods for the newly resolved binary systems in Table I were calculated by assuming that Δm is typically 0.5 mag, that the total mass of each system is 1.8 times the mass of the primary for which the mass and absolute magnitude can be estimated from Allen (1973), that the unknown inclinations are randomly distributed and result in a mean projection factor of 0.64, and that the orbits have a mean eccentricity of 0.5. The estimated values for the distances, orbital semimajor axes, and periods are given in the last three columns of Table I. Seventeen of the new binaries have periods in excess of a century, while 17 systems have periods of less than 40 yr. Five systems (HR 6956, 7272, 7677, 8246, 8581) have periods of 15 yr or less. Although the period estimates are based upon a model and thus are highly uncertain, they can serve as a guide for those objects that should be routinely measured by speckle observers and/or offer a possibility for the determination of spectroscopic orbits.

Figure 1 is a histogram of angular separations smaller than 0".64 measured for the survey sample. The sample is subdivided in Fig. 1 according to whether or not the system is newly resolved, and furthermore, whether previously known binaries were discovered visually or with speckle interferometry. The figure omits 22 systems with angular separations exceeding 0".65, including the newly discovered wide pair comprising HR 8690. Inspection of Fig. 1 leads to the conclusion that for separations exceeding 0".25 visual surveys have reached a completeness which cannot be substantially improved by speckle interferometry. For this "wide" separation regime, five new binaries were found compared to

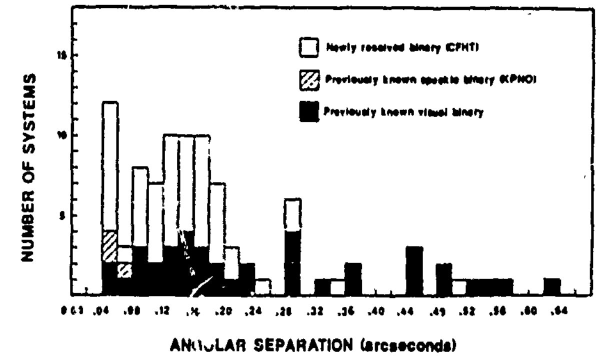

FIG. 1. The histogram of angular separations from 93 measurements of binary systems clearly shows the increase in newly resolved systems at separations less than 0.25 arcsec. An additional 22 measures of systems with separations exceeding 0.65 arcsec are not shown here. Those "wide" binaries include only one newly resolved system.

53 previously known systems. For "close" binaries with separations less than 0".25, our results nearly triple the incidence of duplicity by finding 47 new binaries compared with 26 previously known systems.

The sensitivity of speckle interferometry as a tool for the discovery of close binaries is made even more apparent when it is realized that three of the 26 previously known binaries were originally first resolved by speckle rather than by visual micrometer methods and that another three were discovered by visual interferometry. Table VI lists for comparison the separations at both the survey epochs and the epochs of discovery for the ten visual binaries with current separations less than 0".150. In nearly every case, the discovery separation was substantially larger than what we measured at 1985.5, when the average separation was 0".109 compared with 0".230 at discovery. It is likely that systems with separations less than 0".12 would be overlooked by even the best micrometer observers so that another four visual binaries that we have measured would probably not have been previously resolved had their orbits not presented wider separations at earlier epochs. This discussion would lead to the conclusion that only approximately 14 of the 72 bright close visual binaries we have observed would be detectable by visual observers were the argument not biased by the lack of separation histories of the new binaries and by the fact that bright stars have not been systematically surveyed for many decades. We can only state in summary that, within our survey sample, 52 new binaries have been found by speckle interferometry in the separation regime of 0".04–0".25, compared with 22 previously known visual binaries. This implies a 240% increase in the known incidence of close visual binaries among the bright stars.

We can estimate the number of binary stars that have been overlooked in any separation interval owing to the finite lower limit of resolution imposed upon speckle interferometry by diffraction principles. For the CFHT, we take the diffraction limit as defined by the Rayleigh criterion and adopt a limiting resolution of 0".038. A simple model from which we can then estimate discovery incompleteness is provided by considering a sphere whose radius equals the upper limit R to an observable separation interval. The sphere then contains all possible vector separations which we assume to be randomly distributed and which would project onto the

TABLE VI. Visual binaries with observed separations less than 0.150 arcsec.

BR	ADS	Disc.	1985.5 Separation	Discovery Separation	Discovery Year
5774	9688	A 1634 AB	0.″040	0.″09	1907
6488	10531	Hu 1179 AB	0.069	0.23	1905
6560	-	Mlr 571	0.140	0.18	1979
6814	11149	B 2545 AB	0.102	0.11	1958
6999	11520	A 88 AB	0.141	0.14	1900
7033	11593	B 2546 AB	0.145	0.2	1958
7840 B	13946	Da 1 BC	0.108	0.5	1841
8116	14761	Hu 767	0.090	0.17	1904
8533	15902	Bu 172 AB	0.121	0.46	1875
8612	16130	A 2695	0.136	0.22	1913

plane of the sky bisecting the sphere to present the distribution of angular separations we attempt to observe. The fraction of the vector separations that would be unresolvable is then given by the intersection of a cylinder of radius r, the diffraction limit, with the sphere such that the cylinder's long axis is perpendicular to the plane of the sky and passes through the center of the sphere. The fraction of the binaries that would then be unresolved can be shown to be given by

$$f=(2r^2H+3Rh^2-h^3)/2R^3,$$

where

$$H\equiv R\cos(\arcsin r/R)$$

and

$$h\equiv R-H.$$

With the limitations of this simple model in mind, we show in Table VII the resulting incompleteness for observed separation intervals beginning at the CFHT diffraction limit, where everything is unresolved, to a separation of 1 arcsec, where an insignificantly small percentage will be overlooked. In the range of separations out to 0.″12, 10% of the binaries will be unresolved due to their orbital inclinations. This implies that approximately three close systems were overlooked in the survey sample due to this effect. The effect of nonzero orbital eccentricities will be to increase the probability of a given system being resolved because of the resulting bias, arising from Kepler's second law, toward larger separations. This effect is complicated and somewhat nullified by the distribution of the longitudes of perihelion. In the present estimate, we expect that a more realistic incompleteness model would not alter the conclusion that three close systems have been overlooked due to the distribution of the orbital elements i, e, and ω.

IV. CONCLUSIONS

From a survey of 672 stars selected from the Yale *Bright Star Catalogue* and observed with speckle interferometry at the 3.6 m Canada-France-Hawaii telescope, we detected and measured the duplicity of 52 stars not previously directly resolved. The separations and position angles of 60 additional, previously known visual binaries have been measured with high accuracy. For 560 stars, our observations showed no indications of companions within a resolution window whose lower limit is approximately 0.″038 and magnitude difference $\Delta m<2$. From these observations we conclude that:

(1) About 500 previously unresolved binary stars can be expected to be discovered from a complete speckle interferometric inspection of all the stars in the BSC.

(2) These new binaries primarily fall into orbital-period regimes likely to be overlooked in traditional radial-velocity and visual-micrometry surveys for duplicity and consequently serve to increase the known overall duplicity rates for stars. Without regard to spectral type, this overall increase of duplicity frequency is approximately 7%.

(3) The number of visual binaries in the separation range 0.″038–0.″25 is found to be 11% of our sample. This more than triples the value based upon previously existing statistics for classically resolved binaries.

(4) Continued discovery and measurement by interferometric means of binaries among the bright stars can result in a substantial increase in the collection of fundamental data for stellar masses and luminosities, as well as in a significant refinement in our knowledge of the frequency of binary and multiple star systems.

TABLE VII. Estimated incompleteness fractions.

R	f	R	f	R	f
0.″038	1.000	0.″065	0.327	0.″140	0.073
0.040	0.829	0.070	0.284	0.160	0.056
0.042	0.748	0.075	0.249	0.180	0.044
0.045	0.655	0.080	0.219	0.200	0.036
0.048	0.581	0.085	0.195	0.300	0.016
0.050	0.538	0.090	0.174	0.400	0.009
0.055	0.450	0.095	0.157	0.500	0.006
0.058	0.407	0.100	0.142	0.600	0.004
0.060	0.381	0.120	0.099	1.000	0.001

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ICCD SPECKLE OBSERVATIONS OF BINARY STARS. II. MEASUREMENTS DURING 1982–1985 FROM THE KITT PEAK 4 m TELESCOPE

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ABSTRACT

This paper represents the continuation of a systematic program of binary star speckle interferometry initiated at the 4 m telescope on Kitt Peak in late 1975. Between 1975 and 1981, the observations were obtained with a photographic speckle camera, the data from which were reduced by optical analog methods. In mid-1982, a new speckle camera employing an intensified charge-coupled device as the detector continued the program and necessitated the development of new digital procedures for reducing and analyzing speckle data. The camera and the data-processing techniques are described herein. We present 2780 new measurements of 1012 binary and multiple star systems, including the first direct resolution of 64 systems, for the interval 1982 through 1985.

I. INTRODUCTION

This paper is a summary of observational results from a program of binary star speckle interferometry carried out at the Mayall 4 m telescope on Kitt Peak during the interval June 1982 through November 1985. These observations were obtained with a speckle camera that incorporates an intensified charge-coupled device (ICCD) as the detector. All data were reduced digitally using a combination of hardware and software specifically developed for the efficient processing of large volumes of speckle data. Paper I in this series (McAlister *et al.* 1987) presented the results from this camera and analysis system for a survey of bright stars with the 3.6 m Canada-France-Hawaii telescope on Mauna Kea. Our binary star speckle-interferometry program is a second-generation continuation of an effort carried out between 1975 and 1981 on Kitt Peak, in which a photographic speckle camera was used to produce nearly 2800 measures of more than one thousand binary star systems. Those results appeared in a series of 11 papers, the last of which is that of McAlister *et al.* (1984).

A catalog of all modern interferometric observations of binary stars has been compiled by McAlister and Hartkopf (1984) with a completeness date of January 1984. Speckle observations dominate the catalog; more than 3200 measurements had been accumulated by several groups since Gezari *et al.* (1972) first observationally demonstrated the applicability of Labeyrie's method to binary stars. The mean separation of the catalog entries is 0″32, while the median separation is 0″21. Approximately 700 of these measures, or 21% of the data, are for systems with angular separations between 0″021 and 0″100. The catalog contains 118 systems first resolved interferometrically, and there can be no doubt that speckle interferometry has become a major contributor to modern binary star astrometry.

We present here 2780 measures of 1012 binary stars, including the first direct resolution of 64 systems. These new observations double the overall contribution of our program and provide a baseline of almost ten years in the measurement of orbital motion for many systems. We continue to place on our observing program objects which can benefit most from the high angular resolution and high accuracy obtainable from speckle observations at large telescopes. Such objects include potentially resolvable spectroscopic binaries; known visual binaries with small angular separations and rapid motions; occultation and astrometric binary stars; stars that indicate possibly resolvable duplicity through composite spectra, suspected variable radial velocity, and abnormal colors and luminosities; and survey samples of such groups as the bright stars, the nearby stars, Hyades cluster members, and high-velocity stars. Our observing program currently is comprised of some 3000 stars. Although the ICCD speckle camera has been found to be capable of observing stars as faint as $V = +16$, most of the program objects are brighter than $V = +10$. This routine limiting magnitude still represents a gain of 3 mag over the limit of the previously used photographic speckle camera.

II. THE SPECKLE CAMERA SYSTEM

The camera system employed in the speckle program of the Center for High Angular Resolution Astronomy (CHARA) at Georgia State University has been described in its developmental stage by McAlister *et al.* (1982). For the sake of completeness and to provide an updated description of the equipment in its actual operational configuration, we present here a comprehensive discussion of the instrumentation for collecting and reducing speckle data.

The heart of the camera is an RCA SID 53601-X0 all-buried channel "thick" CCD for which RCA had modified its TC 1160 camera in order to provide a standard RS 170 video output from the chip. The RCA camera operates the chip in a frame-transfer mode, shifting an "A" register image into a covered "B" register for readout while another "A" image is being accumulated. The effective photosensitive area of the CCD is thus reduced by 50% to an array of 244×248 pixels. The readout-noise problem is completely eliminated by intensifying the CCD; this was accomplished by fiberoptically coupling an ITT F-4144 dual microchannel-plate intensifier to the CCD. The MCP tube was pro-

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vided by ITT with an 18 mm diameter photocathode. A D-14 fiberoptic plug was bonded by RCA directly to the "A" register of the CCD in order to provide for coupling to the MCP intensifier. Our early experience with this method was disheartening in that the first CCD failed irretrievably during its testing phase and the second device failed in a similar manner in January, 1983, after working flawlessly for one year. With the assistance of RCA, who provided us with the last research-quality CCD of its type in stock, we traced both failures to differential expansion between the CCD substrate and the bonding material for the input fiberoptic that resulted in the failure of the chip preamplifier circuit. Successful bonding using a specially prepared ceramic collar was carried out for us by Lyle Broadfoot and his colleagues at the Earth and Space Sciences Institute in Tucson, Arizona, and the third device has operated continuously since late 1983.

The overall characteristics of the ICCD include a maximum gain of one million, with peak sensitivity at λ 500 nm and 50% of peak sensitivity still available at λ 400 and λ 670 nm. The pixels are 30 μ square and are contiguous. The detector is electronically shuttered by gating the photocathode voltage in synchronism with the video camera. This provides exposure times between 1 and 15 ms, a useful feature when confronted with rapidly varying seeing. The detector has high mechanical stability, is free from image distortions associated with other types of image tubes, and is capable of detecting single photon events. It is ideally suited to binary star astrometry requiring an accuracy of better than 1%, and its sensitivity and near linearity make it an effective detector for photometric purposes. Unfortunately, the CCD has a prominent fixed pattern involving some 15 pixels that contributes to autocorrelation algorithms not employing flat fielding, such as the vector autocorrelation we use, and diminishes the detector's effectiveness on faint objects. We hope to secure a cleaner chip at a future date.

A schematic of the CHARA speckle camera system is shown in Fig. 1. The camera-head assembly contains optics for increasing the effective focal length in order to produce a highly magnified field of view and for collimating the beam in order to eliminate focusing variations due to variable thickness of filters and dispersion-compensation prisms. At the Mayall telescope, a choice from among three microscope objectives provides scales on the detector of 0.0161, 0.0087, 0.0051 arcsec per pixel corresponding to fields of view of 3.96, 2.14, and 1.25 arcsec square. We normally use a 20× microscope objective corresponding to the middle level of magnification. For object acquisition at telescopes not possessing an independent acquisition capability, the camera head was designed so that the microscope objective and collimating lens can be removed from the beam while an additional acquisition lens is inserted to provide a field of view with a diameter of nearly 1 arcmin. At the 4 m telescope, this capability is only used at the beginning of an observing run when it is necessary to provide a fiducial mark on the telescope television acquisition monitor for the small speckle field of view. A filter wheel assembly provides Strömgren u, v, b, y filters, an intermediate-bandwidth filter centered on y, and a clear position. Data are routinely obtained through the Strömgren y filter. Design considerations for the atmospheric-dispersion-compensating Risley prisms are discussed in the description of the original photographic speckle camera used at Kitt Peak (Breckinridge *et al.* 1979). The prisms were designed to permit complete dispersion compensation for zenith angles of up to 65° over bandwidths of 15 nm.

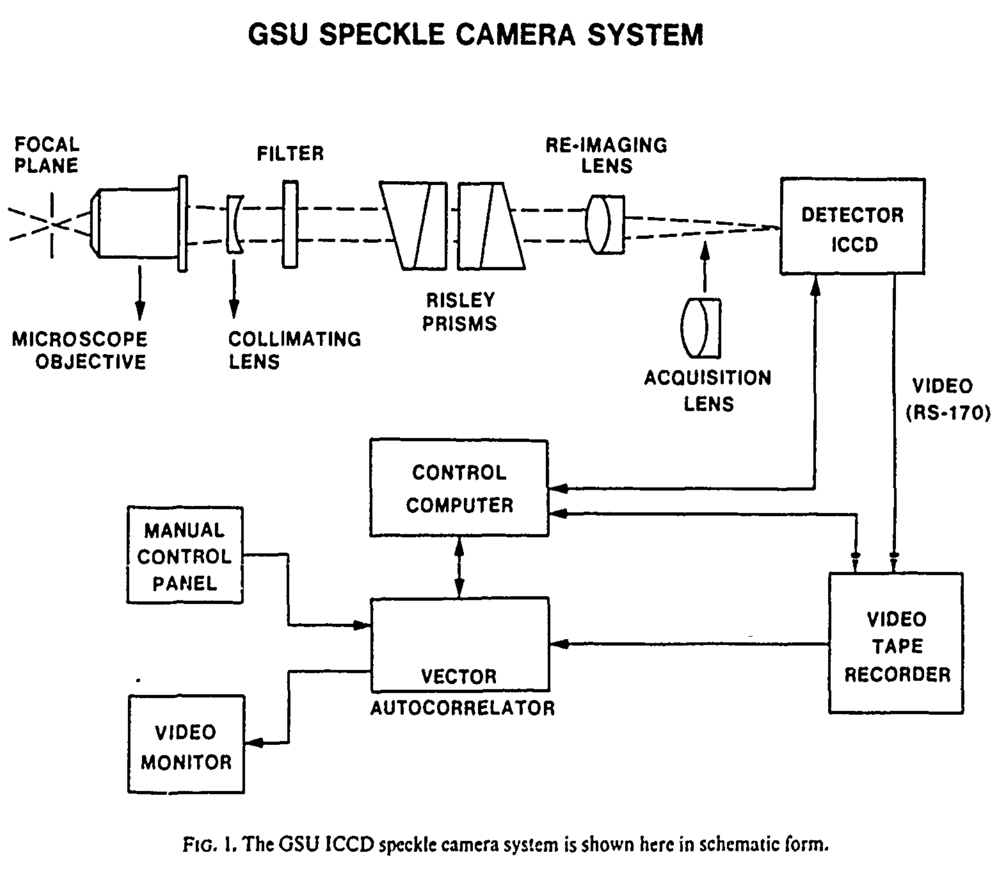

FIG. 1. The GSU ICCD speckle camera system is shown here in schematic form.

All camera-head functions including filter selections, Risley-prism setting, speckle or acquisition field selection, exposure times, integration times, detector gain, and the starting/stopping of the videotape recorder are completely controlled by a Motorola 6809 microprocessor under the direction of an Osborne 1 host computer. This arrangement permits the rapid and accurate setup of the camera from the control room for each object to be observed. As a backup to the Osborne 1, the microprocessor can read/write a Burr-Brown hand-held control/display panel that is otherwise used for local control of the camera head when necessary. This is especially useful during camera installation and testing in the telescope observing cage.

The videotape recorder selected for recording speckle frames is a version of a VHS recorder marketed by RCA and extensively modified by Gyyr Corporation. The modifications included replacing the capstan drive motors with microprocessor-driven stepper motors and tape servo, changes to the recording heads, and the provision of a variable tape canting system. The recorders we purchased were then further modified to include an RS 232 interface port for remote operation by means of the camera-head microprocessor. These modifications of the recorder allow data taking at normal video rates, playback at various rates inlcuding still field, and complete computer control for automated data recording as well as possibly for automated data processing.

A typical observing sequence involves the acquisition of an object by the telescope operator, who then centers it in the speckle camera field of view. Speckle data are then accumulated typically for 60 s; during this time 1800 speckle frames will be recorded on video tape. An example of one such speckle frame is shown in Fig. 2 [Plate 43]. This entire cycle lasts approximately two to three minutes, permitting an observing rate of at least 20 objects per hour. The storage of our 3000-star observing list on the telescope-control computer gives some relief to the otherwise harried telescope operator.

Processing of the vast volume of data generated by the speckle camera is critically dependent upon a hardwired vector autocorrelator (VAC) built to our specifications by Digital Television Imagery, Inc., of Tucson, Arizona. The VAC operates by digitizing an incoming video frame and storing the (x, y) coordinates of only those pixels whose intensities are above an adjustable threshold level. A two-dimensional histogram of all coordinate-pair differences is then calculated and stored in a $128 \times 128 \times 16$-bit autocorrelogram memory. Autocorrelograms from individual frames are continuously coadded, and the result is displayed to the operator. This windowed autocorrelogram can be offset from the origin in order to measure known binaries. As described in Paper I, the autocorrelator was incorporated into the observing activities in the spring of 1985, following construction of an interface that enables the autocorrelogram memory to be read by a DEC Pro 350 computer that stores the autocorrelograms on floppy diskettes for further processing. Prior to that time, the VAC could only be operated in conjunction with a Perkin-Elmer 3220 minicomputer at Georgia State University, and all data processing required the playback of data recorded by the video cassette recorder, a device that now only serves for data archival purposes.

The CHARA speckle camera, whose detailed design and construction was carried out by Technical Development Corp., of Tucson, Arizona, has proved to be an extremely reliable instrument that has fulfilled our specifications in all respects. The camera has been transported to and used at six different telescopes during some 200 nights without suffering any mechanical or electronic failures that could not be repaired prior to the start of the next night's observing.

III. AUTOCORRELOGRAM REDUCTION TECHNIQUES

Techniques developed for reduction of autocorrelograms (ACGs) have been outlined by Hartkopf (1984) and, more recently, by Hartkopf *et al.* (1985). The methods described here have been developed with two major objectives in mind. Foremost, of course, is accuracy; our goal is to derive astrometric information accurate to $\pm 0\overset{''}{.}0003$ or better for binary stars ranging in separation from a few seconds of arc down to the Rayleigh limit ($0\overset{''}{.}025$ for a 4 m telescope). We have succeeded in reaching accuracies of this order for brighter binaries and accuracies of approximately $0\overset{''}{.}001$ for all but the faintest pairs. Our second major objective is, of necessity, speed. As mentioned above and shown in Table I, observing has been streamlined to the point where 200 or more objects can be observed in a single night; as many as 1200 observations may be obtained in one Kitt Peak observing run. The speckle camera is also used in separate projects at other facilities, including observing runs averaging five nights per month on the Perkins 72 in. reflector at Lowell Observatory. It is essential, therefore, that data reduction be streamlined as well, in order to keep up with the continual influx of new observations. Most of the reduction steps described below are, in fact, carried out in a batch process, with human interaction usually needed only for selecting the binary peaks to be fitted. Alternatively, the entire reduction process may be carried out interactively for "problem" ACGs resulting from poorer observing conditions and/or fainter stars. All data reduction is carried out with the CHARA VAX 11/750 computer and image-processing system at GSU.

The memory of our VAC is limited to 16 bits (65K, and

TABLE I. Observing run statistics.

Run	Dates included	Number of nights	Number of observations	Number of resolved measures	Notes
Jun 82	1982.5027—1982.5088	3	244	83	
Oct 82	1982.7542—1982.7661	5	518 (+56)	219	
Jan 83	1983.0471—1983.0511	2	254 (+53)	112	
	1983.0610—1983.0703	4	512 (+29)	167	ISIT
Jun 83	1983.4141—1983.4342	8	750 (+57)	334	
Sep 83	1983.7097—1983.7163	3	460 (+28)	302	
Jan 84	1984.0520—1984.0636	5	692 (+48)	251	
May 84	1984.3724—1984.3870	6	866 (+165)	339	
Sep 84	1984.7007—1984.7129	5	454 (+65)	229	
Dec/Jan 84/85	1984.9965—1985.0114	6	460 (+356)	100	
Jun 85	1985.4729—1985.4730	1	3	3	Lowell 24"
Jun/Jul 85	1985.4812—1985.4985	6	369 (+383)	206	
Nov 85	1985.8350—1985.8545	8	856 (+359)	435	
Total		62	6438 (+1599)	2780	

65 535 counts); any pixel exceeding this limit will "burst" and reset to zero. The central spike of an ACG will often burst one or more times; for a very bright star, less than a minute's worth of data may cause the entire central portion of the ACG to burst many times. The first step in reduction, therefore, must be to "deburst" the data—i.e., to add 65K counts to each pixel as many times as is necessary to restore it to its correct value. Each row of pixels is scanned from both ends toward the center to look for the sudden drop of > 65K that indicates bursting. This pixel is increased by $n \times 65$K, then the next inner pixel is compared to it, etc. The entire process is repeated for each column in a similar manner. Safeguards added to the reduction program recognize and correct most noise spikes and dropouts as well.

This debursting technique seems to work quite well at restoring nearly all pixels to their correct value. It can, however, break down for those pixels encompassing the central spike of the ACG; here the pixels have often burst so many times that it is impossible to correct them. This is not usually of major concern, however, since these pixels typically correspond to separations within the Rayleigh limit. Part (a) of Fig. 3 [Plate 44] illustrates an autocorrelogram of ADS 7158 after debursting. The central spike has been somewhat clipped in order to show the secondary peaks more clearly.

The second reduction step consists of removing the broad seeing-induced background slope from the ACG. Its purpose is twofold. First, this Gaussian-like background can noticeably alter the measured centroid of a secondary peak, even for a wide binary. The background slope varies greatly with distance from the center of the ACG, often in a nonradial manner owing to incomplete correction for atmospheric dispersion or to turbulence-induced asymmetry in the atmospheric point-spread function. Second, removal of this bright background is often necessary to permit detection of secondary peaks as faint as 1% of the background level.

Several background-fitting methods have been tested, including FFT's, radial least-squares polynomials, and a rotate-and-subtract algorithm. The technique now in use is a simple "boxcar" smoothing algorithm, which, in addition to being the most straightforward to calculate, seems to give the most consistently reliable results. A "smoothed" version of the ACG is created by replacing each pixel's value with the average value of an array centered on the pixel. The size of this array is adjustable; typical boxcar sizes are 9×9 or 11×11 pixels. This smoothed ACG is then subtracted from the original—the result is shown in Fig. 3(b).

The next step is to identify features thought to be secondary peaks arising from duplicity and to determine their centroid positions. A cursor is moved to each peak; the program then (1) scans about that position for a local maximum, (2) picks an array of points centered on that maximum, typically 3×3 or 5×5 pixels in size, (3) calculates a least-squares paraboloidal fit to these points, and (4) plots cross-sectional slices through that paraboloid, indicating the centroid position. The operator can then (1) accept the fit, (2) try fitting a different size array of points about the peak, (3) record an "eyeball-fit" cursor position (usually necessary only for very weak peaks or noisy data), or (4) reject the peak altogether. Measured (X,Y) centroid positions are finally converted to (ρ,θ) using scaling factors determined by the calibration techniques described in Sec. IV.

This rather simple reduction and analysis procedure may not provide the maximum sensitivity to large magnitude differences (we are currently experimenting with ways to detect very faint peaks against high background levels), but it has proved a very efficient and dependable means for processing some 15 million speckle frames containing nearly one terabyte of information.

IV. CALIBRATION

Calibration of our speckle data is accomplished by two different methods. The primary calibration continues to be made by placing a double-slit mask over the entrance aperture of the telescope and observing a bright single star—in effect turning the telescope into a Michelson interferometer (see McAlister 1977). The ACG of one such calibration observation is shown in Fig. 4 [Plate 45]; the background has been removed by the boxcar technique described in Sec. III. The separations of these well-defined peaks depend only on the geometry of the telescope/camera system; that is, on the focal lengths of the optical components, the physical separations of the slits in the mask, and the location of the mask in the beam. Thus a scaling factor can be determined that is limited only by the accuracy to which these quantities are known. Calibration accuracies of $\pm 0.6\%$ in separation and $\pm 0^\circ\!.2$ in position angle have been obtained (McAlister 1977). Variations in calibration occur from one observing run to the next owing to changes in the precise placement of the speckle camera at the Ritchey-Chretien focus of the KPNO 4 m telescope. The range of these variations amounts to approximately 2% in angular separation and $0^\circ\!.5$ in position angle. It is therefore necessary to secure calibration data at least once during every observing run.

A secondary calibration of our speckle data is made by observing bright binary systems whose orbits are either very well determined or of extremely long period (see McAlister and Hartkopf 1983 for a list of suggested binary "standards"). These observations give us a useful check on the double-slit calculations. More importantly, they also provide scaling factors when the speckle camera is used on telescopes not equipped with calibration masks, or for which focal lengths, etc., are not known to sufficient accuracy. Because of orbital motion, use of binary stars as a primary calibration can be risky, and we strongly recommend that an external primary calibration procedure be used in order to fully exploit the high precision inherent in speckle interferometry.

V. THE MEASUREMENTS

The observational material incorporated in this paper was accumulated on 61 nights at the 4 m Mayall telescope between June 1982 and November 1985. In Table I we summarize the observing statistics. All data were obtained with the ICCD camera as described in Sec. II, except those between 1983.06 and 1983.07, for which an ISIT acquisition camera borrowed from KPNO was used in place of the failed CCD. We suspect that the ISIT measures may be of somewhat degraded accuracy in comparison with the ICCD values due to the spatial distortions inherent in ISITs. We include in this paper three measurements obtained at the 24 in. refractor of the Lowell Observatory during an experimental exercise aimed at demonstrating the practicability of speckle interferometry at refracting telescopes. While the measurement of HR 7417 (β^1 Cyg = McA 55 Aa) for 1985.4729 does show a systematic departure from the 4 m measurements that bracket it, we find that speckle interferometry works quite well at refracting telescopes. The fourth column

in Table I lists the number of stars for which speckle data were obtained in the observing interval. Numbers shown in this column in parentheses indicate additional observations that were secured in separate efforts, such as for minor planet duplicity, and, primarily, a sample of potential *HIPPARCOS* targets, that have been reduced and analyzed but have not been incorporated in the present paper. The number of actual binary star measurements extracted from the data and given in colum five of Table I shows that only 43% of the data actually resulted in detection and measurement of double stars. This yield fraction is due to the exploratory nature of much of the program, in which we attempt to resolve systems never previously measured as "visual" binaries. Although this approach inevitably leads to a large collection of negative results, it also produced the first resolution of 116 binary stars with the new camera.

Binary stars are traditionally given a designation based upon the name of the discoverer. This practice works well in visual micrometry programs where a single person is responsible for the entire effort. Speckle-interferometry programs tend to be dependent on a group of people, and our program has evolved into a team effort since the retirement of the original photographic speckle camera. We have therefore chosen to give the designation "McA" to the 76 binaries first resolved by the photographic system, and "CHARA" to the 116 new systems detected with the ICCD speckle camera. Table II is a collection of basic information for the McA stars, while such parameters are given in Table III for the

TABLE II. Binary stars first resolved by the KPNO photographic speckle camera.

McA Number	HR/DM Number	Name	HD Number	SAO Number	ADS Number	α,δ (2000)	V Mag	Spectral Classif.	Disc. Sep.	Binary Type
1 Aa	HR 132	51 Psc	2913	109262	449	00323+0657	5.7	B9.5V	0″271	Occn
2	HR 233	-------	4775	11424	-----	00507+6415	5.4	B9.5V+G0III-	0.045	Spm,SB
3	HR 439	-------	9352	22389	-----	01334+5820	5.7	K0Ib+B9V	0.133	Spm
4	+08 0316	-------	12483	110295	-----	02026+0905	7.8	G5IV	0.224	Occn
5	HR 649	ξ^1 Cet	13611	110408	-----	02130+0851	4.4	G6II-IIICN	0.056	SB,Occn
6	HR 640	55 Cas	13474	12180	-----	02145+6631	6.1	B9V+G0II-III	0.077	Spm
7	HR 763	31 Ari	16234	93022	-----	02366+1226	5.7	F7V	0.078	SB,Occn
8	HR 788	12 Per	16739	55793	-----	02422+4012	4.9	F9V	0.055	SB
9	HR 825	-------	17378	23637	-----	02495+5705	6.3	A5Ia	0.186	Spm,Var
10 Aa	HR 838	41 Ari	17573	75596	2159	02500+2716	3.6	B8Vn	0.298	SB
11 Aa	HR 1043	-------	21427	24062	2563	03301+5922	6.1	A2V	0.325	
12	HR 1129	-------	23089	12891	-----	03461+6321	4.8	G0III+A3V	0.045	Spm
13 Aa	HR 1252	36 Tau	25555	76425	2965	04044+2406	5.5	G0III+A4V	0.041	Occn,Spm
14 Aa	HR 1331	51 Tau	27176	76541	-----	04185+2135	5.7	F0V	0.080	SB,Hyad
15	HR 1411	θ^1 Tau	28307	93955	-----	04286+1557	3.8	K0IIIbFe-0.5	0.116	SB,Occn,Hyad
16	HR 1497	τ Tau	29763	76721	-----	04422+2257	4.3	B3V	0.173	Occn,SB
17	HR 1569	6 Ori	31283	94197	-----	04548+1125	5.2	A3V	0.334	Var
18 Aab,c	HR 1788	η Ori	35411	132071	4002	05244-0224	3.4	B1V+B2e	0.044	SB,Var
19 Aa	HR 1808	115 Tau	35671	94554	4038	05271+1758	5.4	B5V	0.095	Occn
20	HR 1876	ϕ^1 Ori	36822	112914	-----	05348+0929	4.4	B0III	0.053	SB
21	+38 1250	-------	37614	58334	-----	05415+3811	8.3	A+G	0.141	Spm
22	HR 2001	-------	38735	150814	-----	05474-1032	6.0	A4V	0.159	SB,Var
23	HR 2002	132 Tau	38751	77592	-----	05490+2445	4.9	G8IIIv	0.043	Occn
24	HR 2130	64 Ori	41040	95166	-----	06034+1942	5.1	B8III	0.066	Occn,SB
25	+26 1082	-------	41600	77980	-----	06074+2640	7.0	B9.5V	0.097	Occn
26	HR 2304	-------	44927	78349	-----	06256+2320	6.1	A2Vn	0.054	Occn
27	HR 2425	53 Aur	47152	78571	-----	06383+2859	5.8	B9npEu	0.064	Occn
28	HR 2605	40 Gem	51688	78947	-----	06595+2555	6.4	B8III	0.080	Occn
29	+37 1645	-------	52823	59741	-----	07043+3734	6.6	A0V	0.158	Spm
30 Aa	HR 2846	63 Gem	58728	79403	6089	07277+2127	5.2	F5V+F5V	0.044	Occn,SB
31 Aa	HR 2861	65 Gem	59148	79434	6119	07298+2755	5.0	K2III	0.038	SB
32	HR 2886	68 Gem	60107	97016	-----	07336+1550	5.3	A1Vn	0.184	Occn
33	HR 3109	53 Cam	65339	14402	-----	08017+6019	6.0	A2pSrCrEu	0.044	SB,Var
34	HR 3880	19 Leo	84722	98767	-----	09474+1134	6.4	A7Vn	0.046	Occn
35	HR 4365	73 Leo	97907	99525	-----	11158+1318	5.3	K3III	0.068	SB
36	HR 4544	-------	102928	138445	-----	11510-0520	5.6	K0IIICN-0.5	0.173	Occn,SB
37	HR 4689	η Vir	107259	138721	-----	12199-0040	3.9	A2IV	0.118	SB,Occn,Var
38 Aa	HR 4963	θ Vir	114330	139189	8801	13100-0532	4.4	A1IVs+Am	0.485	SB,Occn
39	+16 2642	-------	126269	101011	-----	14241+1617	6.8	F5V+A2	0.053	Spm
40	HR 5472	-------	129132	83458	-----	14403+2158	6.1	G0V	0.057	SB
41	-14 4182	-------	136406	159188	-----	15210-1522	7.5	K0III	0.365	Occn
42 CE	HR 5985	β^1 Sco	144218	159683	9913	16054-1948	4.9	B2V	0.127	Occn
43	-21 4279	-------	144641	184141	-----	16077-2124	7.9	G5	0.115	Spm
44	HR 6237	-------	151613	30076	-----	16453+5647	4.8	F2V	0.041	SB
45	HR 6388	-------	155410	46524	-----	17095+4047	5.1	K3III	0.039	SB
46	-19 4547	-------	155095	160326	-----	17103-1926	7.0	B8.5V	0.127	Occn
47	HR 6469	-------	157482	46664	-----	17217+3958	5.5	F9Vn:	0.036	SB
48 Aa	HR 6485	ρ Her	157779	66000	10526	17237+3709	4.1	B9.5III	0.286	
49 Aa	+18 3500	-------	163640	103226	10905	17564+1820	6.6	A0III	0.088	
50	HR 6697	-------	163840	85575	-----	17572+2400	6.3	G2V	0.110	SB
51	-20 5068	17 Sgr	167570	186575	-----	18167-2032	7.1	G5IV+A5	0.260	Occn,Spm
52	-17 5245	-------	171347	161631	-----	18351-1653	7.0	A2V	0.156	Spm
53 Aa	HR 7059	5 Aql	173654	142606	11667	18464-0058	5.9	A2Vm	0.127	Spm,SB
54	+12 3818	-------	178452	104515	-----	19083+1215	7.5	G5IV+A2	0.118	Spm
55 Aa	HR 7417	β^1 Cyg	183912	87301	12540	19307+2758	3.1	K3II+B0.5V	0.444	SB,Spm
56	+58 1929	-------	184467	31745	-----	19311+5835	6.6	K1V	0.117	SB
57	HR 7478	ϕ Cyg	185734	68637	-----	19394+3009	4.7	G8III-IV	0.030	SB
58	+18 4252	-------	187321	105288	-----	19487+1852	7.1	G0I+A	0.408	Spm
59 Aa	+35 3930	-------	190429	69324	13312	20035+3602	6.6	O5.8	0.118	
60 Aa,B	HR 7744	23 Vul	192806	88428	-----	20158+2749	4.5	K3IIICN-1	0.241	
61	+49 3310	-------	196089	49782	-----	20331+4950	6.7	A0+G0V	0.055	Spm

TABLE II. (continued)

McA Number	HR/DM Number	Name	HD Number	SAO Number	ADS Number	α,δ (2000)	V Mag	Spectral Classif.	Disc. Sep.	Binary Type
62	HR 7922	-------	197226	70367	-----	20410+3905	6.5	B6III	0.121	SB
63 Aa	HR 7963	λ Cyg	198183	70505	14296	20474+3629	4.5	B5Ve	0.048	SB
64	HR 7990	μ Aqr	198743	144895	-----	20527-0859	4.7	A3m	0.049	SB
65 Aa	HR 8047	59 Cyg	200120	50335	14526	20598+4732	4.7	B1ne	0.215	SB,Var
66 Aa	HR 8059	12 Aqr	200497	145064	14592	21041-0549	7.3	A3V	0.071	
67 Aa	HR 8119	ι Cep	202214	33210	14749	21118+6000	5.6	B0II	0.052	
68	HR 8264	ξ Aqr	205767	145537	-----	21377-0751	4.7	A7V	0.033	SB,Occn
69 Aa	HR 8417	ξ Cep	209790	19826	15600	22037+6437	4.4	A3m	0.055	SB
70 Ab	HR 8485	-------	211073	72155	15758	22139+3944	4.5	K3III	0.524	SB
71	HR 8572	5 Lac	213310	52055	-----	22295+4743	4.4	M0II+B8V	0.122	SB,Spm
72	+80 0731	-------	215319	3769	-----	22394+8123	6.9	F8+A5V	0.170	Spm
73	HR 8704	74 Aqr	216494	165359	-----	22535-1137	5.8	B9III	0.071	Occn,SB
74 Aa	HR 8866	94 Aqr	219834	165624	16672	23191-1327	5.1	G5IV	0.212	SB
75 Aab	HR 9003	ψ And	223047	53355	-----	23460+4625	4.9	G5Ib+A0V	0.265	Spm
75 Aac	HR 9003	ψ And	223047	53355	-----	23460+4625	4.9	G5Ib+A0V	0.145	Spm
76	HR 9064	ψ Peg	224427	91611	-----	23578+2508	4.7	M3III	0.191	

TABLE III. Binary stars first resolved by the GSU ICCD speckle camera.

CHARA Number	HR/DM Number	Name	HD Number	SAO Number	ADS Number	α,δ (2000)	V Mag	Spectral Classif.	Disc. Sep.	Binary Type
1 Aa	+52 0019	---------	761	21202	148	00122+5337	7.0	F0	0.403	
2	+83 0020	---------	5621	171	-----	01037+8436	6.7	F5V	0.139	Spm
3	+67 0131	---------	9015	11787	-----	01308+6722	9.2	K0	0.247	
4 Aa	HR 526	---------	11031	37536	1438	01492+4754	5.8	A3V	0.141	SB
5	HR 643	60 And	13520	37867	-----	02132+4414	4.8	K3.5IIIBa0.5	0.187	SB
6 Ap	HR 707	ι Cas	15089	12298	1860	02290+6724	4.5	A5pSr	0.496	SB,Var
7	+43 0576	---------	17245	38335	-----	02475+4416	6.7	F5V+A	0.159	Spm
8	HR 952	---------	19789	93327	-----	03114+1303	6.1	K0IIIp	0.533	Occn
9	+28 0532	UX Ari	21242	75927	-----	03266+2843	6.5	G5IV/V+K0IV	0.432	SB,Var
10	HR 1036	---------	21335	93436	-----	03271+1845	6.6	A3V	0.076	Occn,Hyad
11	+23 0496	---------	23157	76103	-----	03437+2339	7.9	A9V	0.232	Occn
12	+23 0523	---------	23489	76173	-----	03465+2415	7.4	A2V	0.230	Occn
13	+19 0662	---------	25811	93759	-----	04063+1952	8.6	F0	0.070	Occn
14	+23 0635	---------	284163	------	-----	04119+2338	9.4	K0	0.138	SB,Hyad
15	Ross 29	Gl 165	------	------	-----	04120+5016	15.5	M5	0.989	Nearby Star
16	HR 1375	---------	27742	76585	-----	04235+2059	6.0	B8IV-V	0.182	Occn
17	+14 0721	vB 96	285931	94009	-----	04340+1510	8.7	K1	0.147	SB,Hyad
18 Aa	HR 1458	88 Tau	29140	94026	3317	04357+1010	4.4	A3	0.104	SB
19	HR 1528	---------	30453	57444	-----	04493+3235	5.9	A8m	0.041	Spm,SB
20	+14 0770	vB 120	30712	94159	-----	04506+1505	7.7	G5	0.072	SB,Hyad
21	+43 1315	---------	36948	40487	-----	05373+4404	7.5	F8+A0V	0.125	Spm
22	HR 2273	7 Mon	44112	133114	-----	06197-0749	5.3	B2.5V	0.055	SB
23	+23 1346	---------	44926	78348	-----	06255+2327	6.8	G5IV	0.104	Occn
24	+16 1273	---------	48954	96097	-----	06468+1646	6.7	F5+A5V	0.489	Occn,Spm
25	+02 1483	---------	51566	114692	-----	06580+0218	7.7	A2+G0V	0.910	Spm
26	HR 2837	61 Gem	58579	79391	-----	07269+2015	5.9	F2Vn	0.030	SB,Occn
27	+08 1791	---------	59604	115545	-----	07309+0833	7.2	A2+G0V	0.261	Spm
28	+20 2159	40 Cnc	73666	80336	-----	08402+2001	6.6	A1V	0.425	Overlum
29	+54 1323	---------	233666	27352	-----	09423+5328	9.3	G0	0.354	Halo
30	HR 3973	14 Sex	87682	118111	-----	10068+0537	6.2	K1III	0.132	Occn
31	+13 2274	---------	91498	99185	-----	10341+1222	7.7	A3V	0.192	
32	+12 2266	---------	93993	99321	-----	10511+1135	6.8	K0III	0.429	Occn
33	HR 4291	58 Leo	95345	118610	-----	11006+0337	4.8	K1IIICN-0.5	0.235	Occn
34 Aa	+30 2097	---------	95515	62361	-----	11018+2952	7.2	K0III	0.242	
35	+22 2411	---------	------	------	-----	11516+2207	9.3		0.176	Halo
36	-04 3155	TY Vir	103036	138451	-----	11518-0546	8.2	K2	0.234	Halo
37	HR 4668	---------	106760	62928	-----	12165+3304	5.0	K0.5IIIb	0.248	SB,Var
38	HR 4891	38 Vir	111998	139022	-----	12532-0333	6.1	F5V	0.442	Occn
39 Aa	HR 4921	44 Vir	112846	139086	8727	12597-0348	5.8	A3V	0.107	Occn
40	HR 5298	96 Vir	123630	158385	-----	14090-1020	6.5	G8III	0.287	Occn
41 AC	HR 5323	14 Boo	124570	100925	-----	14141+1258	5.5	F6IV	0.190	SB
42 Aa	+02 2844	---------	128563	120569	9323	14373+0217	6.6	F8V	0.210	
43	HR 5612	---------	133484	45348	-----	15031+4439	6.7	F6IV	0.166 •	
44	-12 4227	---------	135681	159146	-----	15168-1302	7.1	A2V	0.193	Occn,SB,Var
45 Aa	+27 2477	---------	136176	83756	9578	15183+2649	6.6	F8V	0.333	Astrom,Var
46	HR 5715	---------	136729	29487	-----	15201+5158	5.7	A4V	0.217 •	
47	HR 5818	---------	139493	29588	-----	15360+5438	5.7	A2V	0.514 •	
48	-19 4165	---------	139364	159402	-----	15384-1955	6.8	F2V	0.271	Occn
49	HR 5858	26 τ Ser	140729	101712	-----	15447+1716	6.1	A0V	0.130 •	SB
50 Aa	HR 5856	---------	140722	183772	9775	15462-2804	6.5	F2IV	0.216	
51	HR 5895	36 Ser	141851	140801	-----	15513-0305	5.1	A3Vn	0.126 •	
52 Aa	+13 3091	49 Ser	145958	102018	9969	16133+1333	6.7	G8V+K0	0.209	
53 Aa	HR 6103	ξ CrB	147677	65254	-----	16221+3053	4.9	K0III	0.153	Hyad
54	-16 4280	---------	147473	159888	-----	16229-1701	6.7	F0V	0.081	Occn
55	HR 6123	25 Her	148283	65290	-----	16254+3724	5.5	A5V	0.195 •	

TABLE III. (continued)

CHARA Number	HR/DM Number	Name	HD Number	SAO Number	ADS Number	α,δ (2000)	V Mag	Spectral Classif.	Disc. Sep.	Binary Type
56 Ba	HR 6194	36 Her	150379	121774	10149	16406+0412	6.9	A3IV	0.145 *	
57	HR 6213	39 Her	150682	84543	-----	16416+2655	5.9	F2III	0.126 *	SB
58	HR 6286	---------	152812	46349	-----	16533+4725	6.0	K2III	0.292 *	
59	HR 6317	---------	153653	121995	-----	17005+0635	6.6	A7V	0.128 *	SB
60 Aa	HR 6383	---------	155328	30262	10369	17083+5051	6.5	A1V	0.168 *	
61	HR 6412	---------	156208	122224	-----	17162+0211	6.2	A2V	0.136 *	
62 Aa	+58 0946	---------	------	17568	-----	17365+6823	9.2	MB	0.292	Astrom
63	HR 6571	79 Her	160181	85264	-----	17375+2419	5.6	A2Vn	0.080 *	
64	HR 6641	---------	162132	46954	-----	17471+4737	6.4	A2Vs	0.142 *	SB
65	HR 6656	30 Dra	162579	30591	-----	17491+5047	5.0	A2V	0.120 *	
66	-19 4777	---------	163680	160947	-----	17582-1916	8.7	K2	0.392	Occn
67 Aa	HR 6781	100 Her	166045	85753	11089	18078+2606	5.9	A3V	0.106 *	Var
68	HR 6851	---------	168199	103578	-----	18180+1347	6.3	B5V	0.054 *	
69	-16 4836	---------	168701	161385	-----	18218-1619	7.9	K0III+A	0.089	Spm
70	HR 6906	---------	169820	103709	-----	18259+1458	6.4	B9V	0.118 *	
71	HR 6928	---------	170200	123516	-----	18280+0612	5.7	B8III-IV	0.078 *	SB
72 Aa	HR 6941	---------	170580	123571	11399	18301+0404	6.7	B2V	0.149 *	
73	HR 6956	---------	170902	161580	-----	18323-1439	6.4	A4V	0.040 *	
74	HR 6977	---------	171623	103879	-----	18352+1812	5.8	A0Vn	0.151 *	SB
75	HR 6984	---------	171780	67134	-----	18352+3427	6.1	B5Vne	0.241 *	SB,Var
76 Aa	HR 6987	---------	171834	123693	11496	18367+0640	5.5	F3V	0.141 *	SB
77 Ca	HR 7053	ε¹ Lyr	173607	67315	11635	18444+3937	5.1	A8Vn	0.184 *	Var
78	HR 7035	---------	173117	187216	-----	18448-2501	5.8	B5:V	0.084	Occn
79	HR 7091	---------	174369	86462	-----	18492+2503	6.6	A1V	0.219 *	SB
80	HR 7109	---------	174853	104196	-----	18520+1358	6.1	B8Vnn	0.104 *	
81	HR 7110	---------	174866	142741	-----	18530-0935	6.3	A7Vn	0.178 *	
82 Aa	HR 7165	FF Aql	176155	104296	11884	18582+1722	5.4	F8Ib	0.154	SB,Var
83	HR 7263	---------	178476	86843	-----	19081+2142	6.2	F3V	0.177 *	
84 Aa	HR 7272	---------	178911	67879	12101	19091+3436	6.7	G1V	0.090 *	
85 Aa	HR 7307	---------	180555	104668	12248	19164+1423	5.6	B9.5V	0.051 *	
86 Aa	HR 7386	---------	182807	87190	-----	19254+2455	6.2	F7V	0.181 *	
87	HR 7436	---------	184603	68499	-----	19336+3846	6.6	A3Vn	0.137 *	
88 Aa	HR 7480	45 Aql	185762	143678	12775	19407-0037	5.7	A3IV	0.084 *	
89	HR 7554	V1339 Aql	187567	125116	-----	19503+0754	6.5	B2.5IVe	0.057 *	Var
90	HR 7571	V505 Sgr	187949	163080	-----	19531-1436	6.5	A0V+F8IV	0.291 *	SB,Var
91	HR 7684	---------	190781	49152	-----	20045+4814	6.0	A2IV	0.340 *	
92	HR 7677	---------	190590	88163	-----	20050+2313	6.5	A5Vn	0.050 *	
93	HR 7755	---------	192983	32400	-----	20157+5014	6.3	A2Vn	0.176 *	
94 Aa	HR 7744	23 Vul	192806	88428	-----	20158+2749	4.5	K3IIICN-1	0.067	
95	HR 7752	---------	192934	69720	-----	20161+3854	6.3	A1V	0.176 *	
96 Aa	HR 7767	---------	193322	49438	13672	20181+4044	5.8	O9V	0.047 *	
97	HR 7801	---------	194215	189264	-----	20254-2840	5.8	K3V	0.121	SB
98	-2416056	---------	194810	189321	-----	20285-2410	6.9	G0V	0.234	Occn
99 Aa	HR 7840	---------	195482	106195	13946	20312+1116	7.1	B8V	0.325	
100 Aa	HR 7949	ε Cyg	197989	70474	14274	20462+3358	2.5	K0III	0.067	SB
101	HR 7994	---------	198802	163953	-----	20531-1134	6.4	G1V	0.169 *	
102	HR 8246	---------	205314	51019	-----	21329+4959	5.8	A0V	0.043 *	SB
103	HR 8257	---------	205539	89815	-----	21353+2812	6.3	F0IV	0.184 *	SB
104	HR 8274	---------	206027	89870	-----	21387+2530	6.2	G9III	0.099 *	
105	+08 4714	EE Peg	206155	126971	-----	21400+0911	6.8	A4V+F5V	0.252	SB,Var
106	HR 8455	---------	210460	107706	-----	22103+1937	6.2	G0V	0.465	
107	HR 8507	---------	211575	146004	-----	22181-0014	6.4	F3V	0.104 *	
108	HR 8538	β Lac	212496	34395	-----	22236+5214	4.4	G8.5IIIbCa1	0.219	
109	HR 8553	---------	212978	72358	-----	22274+3949	6.1	B2V	0.185 *	
110	HR 8574	38 Peg	213323	72406	-----	22300+3234	5.6	B9.5V	0.155 *	
111	HR 8581	---------	213429	146135	-----	22313-0633	6.1	F7V	0.094 *	
112 Aa	HR 8603	8 Lac	214168	72509	16095	22359+3938	5.7	B2Ve	0.042 *	SB,Var
113	+68 1319	---------	214606	20179	-----	22373+6913	7.5	A3+G0V	0.487	Spm
114	HR 8617	---------	214558	52211	-----	22383+4511	6.4	G2III+A4V	0.114 *	
115	HR 8690	14 Lac	216200	52412	-----	22504+4157	5.9	B3IV:e	0.965 *	Var
116	HR 8734	---------	217107	146412	-----	22583-0224	6.2	G8IV	0.457	Occn

CHARA stars. References to the discovery papers for the McA stars can be found in the catalog of McAlister and Hartkopf (1984). The CHARA stars include 52 objects resolved in our bright-star survey (Paper I) and 64 systems appearing in this paper. An asterisk by the discovery separation in Table III indicates the stars from Paper I. The last column in Tables II and III shows whether the object is a spectroscopic (SB), composite spectrum (Spm), occultation (Occn), or astrometric (Astrom) system, or whether it is a member of the Hyades cluster (Hyad), a variable star, an overluminous star, or a halo-population star. The halo stars were selected from the sample of extreme metal-poor stars of Bond (1980). The average V magnitude of the CHARA stars is 6.8 when the bright star sample of Paper I is excluded. This value is 1.1 mag fainter than the average value of V for the McA stars. Even though we can now detect faint binaries, as demonstrated by the discovery of the new companion to Ross 29, the ICCD speckle camera continues to be productively used on brighter stars.

The new speckle measurements of binary stars are presented in Table IV, where we continue the format used in previous papers and the catalog of McAlister and Hartkopf (1984) except that we give HD numbers on the identification line, omitting SAO numbers. The coordinates are for equinox of 2000.0, but the position angles have not been corrected for precession and hence are based upon the equinox for the epoch of observation shown as the fractional Besselian year. The reader should also keep in mind that autocorrelation analysis of speckle data leads to a 180° quadrant ambiguity in position angle. We have selected the appropri-

TABLE IV. Binary star speckle measurements.

ADS 32	STF 3056 AB		225220	00046+3416
	1983.7104	143°2		0″695
	1984.7069	143.0		0.695
	1985.8429	142.5		0.704
ADS 61	STF 3062 AB		123	00062+5826
	1982.7601	292.5		1.399
	1983.7104	294.6		1.420
	1984.7069	296.6		1.415
	1985.8483	298.7		1.426
ADS 102	STF 2		431	00091+7943
	1982.5087	24.8		0.606
	1982.7576	25.0		0.616
	1983.0688	24.2		0.603
	1984.0547	24.8		0.616
	1984.7015	25.2		0.621
	1985.8429	24.0		0.636
ADS 143	STF 7		709	00116+5558
	1985.8483	212.6		1.290
ADS 147	Bu 255		744	00119+2825
	1983.7104	77.4		0.524
	1985.8429	76.0		0.525
ADS 148	Bu 1026		761	00122+5337
	1982.5060	34.7		0.127
	1982.7576	33.6		0.135
	1983.7104	43.3		0.117
	1984.0547	53.2		0.129
	1984.7015	55.6		0.084
	1985.8455	86.2		0.053
ADS 148	CHARA 1 Aa		761	00122+5337
	1982.7576	0.0		0.403
	1983.7104	3.9		0.322
	1984.0547	27.5		0.210
ADS 197	A 1256 AB		1082	00152+4406
	1982.5088	62.7		0.137
	1983.7104	67.1		0.126
	1984.7015	65.7		0.114
	1985.8401	67.8		0.110
	1985.8455	67.9		0.110
ADS 207	STF 13		1141	00163+7657
	1982.5088	59.8		0.892
	1982.7600	58.6		0.893
	1983.0688	58.5		0.886
	1984.0547	58.4		0.885
	1985.8429	57.8		0.902
ADS 238	A 1803 AB		1317	00173+0852
	1985.8429	142.4		0.051
ADS 243	A 803		1360	00182+7256
	1983.0688	272.0		0.180
	1983.7104	276.7		0.189
	1984.0547	275.8		0.176
	1984.7015	278.1		0.192
	1985.8402	279.1		0.196
	1985.8456	278.5		0.198
ADS 328	Hu 506		1976	00243+5201
	1983.7104	46.1		0.172
	1984.0547	45.6		0.173
	1984.7015	47.0		0.169
	1984.9991	47.2		0.168
	1985.8402	47.8		0.168
	1985.8455	47.6		0.168
HR 108	B 1909		2475	00283-2020
	1982.7657	175.7		0.071
ADS 382	A 1504 AB		2471	00287+3718
	1983.7104	38.5		0.525
	1984.7014	38.3		0.521
	1985.8401	38.0		0.529
ADS 434	STT 12		2772	00318+5432
	1982.7545	185°8		0″474
	1982.7576	185.8		0.473
	1983.7104	187.1		0.461
	1984.0547	187.1		0.456
	1984.0602	186.8		0.461
	1984.7015	187.3		0.457
	1984.9991	187.4		0.455
	1985.8402	187.3		0.457
+26 0072	Cou 547		2854	00320+2740
	1984.0627	247.2		0.131
	1985.8455	198.3		0.054
ADS 449	McA 1 Aa		2913	00323+0657
	1983.7104	92.6		0.168
	1984.7014	88.4		0.138
	1984.9991	87.4		0.130
	1985.8429	82.9		0.104
ADS 463	Ho 3		2993	00335+4906
	1985.8401	124.8		0.264
ADS 490	Ho 212 AB		3196	00352-0336
	1982.7603	243.9		0.255
	1982.7657	244.6		0.257
	1983.7104	260.7		0.287
	1984.7014	273.7		0.287
	1984.9991	277.3		0.280
	1985.4985	285.7		0.269
ADS 493	STT 15		3210-1	00358+4901
	1983.7104	317.7		0.209
	1984.0547	316.5		0.210
	1984.7015	317.8		0.211
	1984.9991	318.5		0.210
	1985.8401	317.5		0.212
ADS 504	A 914		3304	00366+5608
	1983.7104	34.7		0.433
	1984.7015	34.6		0.430
	1985.8402	33.4		0.433
HR 178	WRH		3883	00416+2438
	1982.7601	16.1		0.172
	1984.9991	29.4		0.142
ADS 684	Bu 232 AB		4777	00504+5038
	1985.8403	241.4		0.836
HR 233	McA 2		4775	00507+6415
	1984.7015	342.8		0.028
	1984.9993	329.8		0.049
ADS 701	A 1808		4934	00516+2238
	1983.7106	169.8		0.079
	1984.9993	168.3		0.093
	1985.8457	171.5		0.101
	1985.8538	173.5		0.102
ADS 732	A 2307		5143	00532+0406
	1983.0690	40.1		0.311
	1983.7106	43.8		0.325
	1985.8313	44.0		0.326
+42 0196	Cou 1654		5178	00542+4318
	1983.0690	108.6		0.159
	1983.7106	109.6		0.159
	1985.8403	105.6		0.165
ADS 746	STT 20 AB		5267	00546+1912
	1982.7601	216.9		0.448
	1983.0690	215.6		0.444
	1983.7106	216.3		0.448
	1984.9966	214.2		0.447
	1985.8484	212.4		0.455
ADS 749	Hu 802		5259	00549+4924
	1983.0690	217.4		0.336
	1983.7106	219.0		0.350
	1984.7017	219.2		0.343
	1984.9965	218.1		0.345
	1984.9993	217.5		0.349
	1985.8456	218.7		0.345

TABLE IV. (continued)

ADS 755	STF 73 AB	5286	00550+2338
	1982.7601	263°5	0″633
	1983.0690	265.9	0.630
	1983.7159	268.3	0.644
	1985.8484	274.5	0.671
ADS 784	Bu 1099 AB	5408	00568+6022
	1982.5088	314.1	0.205
	1982.7601	312.0	0.201
	1983.0690	312.7	0.217
	1984.0547	315.6	0.210
	1984.7015	317.4	0.213
	1984.9965	318.2	0.219
	1984.9993	317.8	0.214
	1985.8402	319.8	0.228
ADS 819	A 1902	5781	00593-0040
	1983.7106	176.5	0.285
	1985.8403	179.3	0.302
ADS 832	A 926	5851	01011+6021
	1983.7104	321.2	0.376
	1985.8402	322.5	0.375
+34 0164	Cou 854	5955	01014+3535
	1983.7106	14.6	0.131
	1985.8457	7.4	0.132
ADS 836	A 2901	5839	01015+6921
	1982.7600	52.2	0.395
	1983.7104	54.2	0.398
	1984.0547	53.2	0.394
	1984.7015	53.7	0.398
	1984.9965	56.2	0.397
	1985.8402	54.0	0.404
ADS 859	Bu 1161	6084	01029+5148
	1983.0690	2.3	0.359
	1983.7106	5.3	0.355
	1984.7015	5.2	0.352
	1985.8403	5.2	0.352
ADS 862	STT 21	6114	01030+4723
	1985.8483	174.1	0.980
+62 0191	MLR 87	6129	01036+6341
	1983.0690	100.8	0.305
	1983.7104	101.0	0.306
	1984.0547	99.8	0.306
	1984.7015	100.4	0.306
	1985.8402	95.1	0.308
ADS 871	Hu 517	------	01037+5026
	1983.0690	25.5	0.542
	1983.7106	27.4	0.541
	1985.8403	27.0	0.547
------	CHARA 2	5621	01037+8436
	1984.0547	90.3	0.139
ADS 873	Ho 213	6264	01039+3528
	1983.0690	94.5	0.286
	1983.7106	95.6	0.291
	1984.7017	96.3	0.290
	1984.9966	96.5	0.290
	1985.8457	96.9	0.290
ADS 916	A 931	6553	01070+4744
	1985.8456	90.4	0.079
ADS 918	A 1516 AB	6586	01071+3839
	1985.8456	62.7	0.145
ADS 936	AC 13 AB	6757	01088+4512
	1983.0690	263.0	0.584
	1983.7106	264.0	0.591
	1985.8484	263.1	0.595
ADS 940	STT 515	6811	01093+4715
	1983.0690	134.7	0.470
	1983.7159	135.7	0.465
	1984.0602	135.8	0.463
	1984.9966	134.6	0.467
	1985.8484	133.4	0.475
ADS 955	Bu 303	6886	01096+2348
	1983.0690	291°3	0″643
	1983.7159	290.8	0.651
	1984.7043	290.7	0.649
	1985.8374	290.3	0.652
	1985.8484	290.3	0.652
ADS 950	Egg 1 Aa	6843	01100+5202
	1984.7045	150.6	0.058
	1985.8403	152.0	0.058
ADS 1039	Hu 520	7695	01178+4946
	1983.0690	164.3	0.290
	1983.7106	165.6	0.294
	1984.7043	165.6	0.296
	1985.8430	164.4	0.302
ADS 1040	STF 102 AB	7710	01178+4901
	1983.0690	279.0	0.485
	1983.7106	280.0	0.489
	1984.7043	279.8	0.487
	1984.9966	280.1	0.492
	1985.8430	279.2	0.492
+32 0229	Cou 663	7854	01187+3245
	1983.0690	173.9	0.313
	1983.7106	175.5	0.302
	1984.7043	175.2	0.306
	1985.8430	174.7	0.311
ADS 1081	STF 113 A,BC	8036	01198-0029
	1982.7629	14.5	1.588
	1982.7657	14.4	1.580
	1983.7106	15.9	1.548
	1985.8430	16.2	1.560
ADS 1081	Fin 337 BC	8036	01198-0029
	1982.7629	127.8	0.132
	1982.7657	127.6	0.121
	1983.7106	132.6	0.102
	1985.8430	246.6	0.115
ADS 1087	HJ 2036	8071	01199-1548
	1982.7629	345.0	2.077
ADS 1105	STF 115 AB	8272	01233+5808
	1983.0690	125.1	0.113
	1983.7107	120.5	0.067
	1984.7045	326.2	0.032
	1985.8430	311.4	0.081
ADS 1123	Bu 1163	8556	01243-0655
	1982.7629	213.0	0.353
	1982.7657	212.9	0.354
	1983.7106	213.3	0.334
	1984.9966	211.2	0.295
	1984.9994	211.2	0.297
	1985.8429	208.9	0.269
ADS 1183	A 1910 AB	9071	01296+2250
	1983.7106	102.4	0.029
+67 0131	CHARA 3	9015	01308+6722
	1983.0691	344.2	0.247
HR 439	McA 3	9352-3	01334+5820
	1984.7045	117.8	0.125
	1985.8430	113.6	0.119
ADS 1226	A 816	9454	01357+7226
	1983.0663	307.4	0.791
	1983.7107	308.1	0.785
	1985.8430	307.6	0.798
ADS 1263	A 817	9841	01371+4843
	1983.0662	30.6	0.456
	1983.7106	31.7	0.457
	1985.8430	30.5	0.464
	1985.8485	30.2	0.462
HR 466	Kui 7	10009	01376-0924
	1982.7657	49.7	0.070
	1985.8429	2.2	0.096
UV Cet	GL 65	------	01388-1758
	1982.7548	52.4	1.971
ADS 1264	Hu 1030	9721	01389+7644
	1983.0663	319.2	0.736
	1983.7107	320.2	0.728
	1985.8430	319.7	0.739

TABLE IV. (continued)

ADS 1286	A 1266	10031	01392+5436
	1983.0663	235.0	0.221
	1983.7130	236.0	0.224
	1984.7045	235.7	0.219
	1985.8430	236.6	0.220
ADS 1309	A 1267	10146	01405+5457
	1983.0663	0.0	0.258
	1983.7107	2.1	0.261
	1984.7045	2.3	0.261
	1985.8430	1.8	0.265
ADS 1318	Kr 12	10196	01415+6240
	1983.0663	294.3	0.431
	1983.7107	294.6	0.433
	1985.8430	293.8	0.427
ADS 1345	A 1	10508	01424-0646
	1983.7106	242.3	0.762
ADS 1359	Bu 870	10543	01443+5732
	1985.8430	0.9	0.845
ADS 1438	CHARA 4 Aa	11031	01492+4754
	1984.7070	14.0	0.141
+25 0311	Cou 452	11245	01510+2551
	1983.7106	181.6	0.271
	1984.7046	181.6	0.267
	1985.8375	179.6	0.291
ADS 1461	A 951	11126	01512+6021
	1983.0663	217.4	0.426
	1983.7107	218.8	0.431
	1984.7045	218.9	0.431
	1985.8431	218.5	0.438
ADS 1473	Ho 311	11284	01512+2439
	1985.8538	290.3	0.065
ADS 1490	I 450	11435	01519-2309
	1984.7070	219.4	0.506
ADS 1509	A 953	11472	01547+5955
	1983.0663	67.6	0.777
	1983.7107	68.7	0.787
	1985.8431	67.7	0.793
ADS 1522	STF 183 AB	11671	01551+2847
	1983.0662	175.4	0.264
	1983.7131	175.0	0.275
	1984.7046	173.3	0.279
	1985.8375	171.2	0.289
ADS 1538	STF 186	11803	01558+0151
	1982.7629	56.8	1.259
	1982.7657	56.8	1.255
	1983.7131	58.0	1.242
	1984.7070	57.8	1.230
	1984.9967	58.0	1.219
ADS 1548	A 819 AB	11849	01570+3101
	1983.0662	194.3	0.352
	1983.7131	198.6	0.352
	1984.7045	200.3	0.346
	1985.8375	202.1	0.331
ADS 1554	A 1526	11869	01576+4433
	1983.0662	254.9	0.138
	1983.7130	260.4	0.138
	1984.7045	259.9	0.134
ADS 1598	Bu 513 AB	12111	02019+7054
	1983.7130	213.9	0.729
	1984.9966	217.9	0.747
	1985.8430	220.3	0.765
ADS 1615	STF 202	12446-7	02020+0246
	1982.7549	283.1	1.910
	1983.7131	282.7	1.903
	1984.7070	282.1	1.886
	1984.9966	281.8	1.882
ADS 1613	A 1813 AB	12376	02022+3643
	1985.8486	4.9	0.159
+08 0316	McA 4	12483	02026+0905
	1982.7603	139.6	0.215
	1983.0662	138.2	0.204
	1983.7131	139.5	0.216
	1985.8538	140.5	0.223
ADS 1630	STT 38 BC	12534	02035+4223
	1982.7605	108.8	0.578
	1983.7159	108.8	0.575
	1985.8485	107.6	0.579
+69 0129	MLR 375	12300	02038+7013
	1983.0663	207.9	0.264
	1983.7107	210.8	0.255
	1985.8430	209.0	0.240
+34 0379	Cou 1067	13102	02090+3541
	1985.8486	14.0	0.101
ADS 1682	STF 216	13196	02114+6222
	1983.7107	13.4	0.212
HR 649	McA 5	13611	02130+0851
	1985.8375	42.2	0.047
HR 643	CHARA 5	13520	02132+4414
	1983.7130	180.4	0.187
ADS 1709	STF 228	13594	02141+4729
	1983.0663	265.7	1.048
	1984.7070	271.3	1.054
	1985.8538	271.7	1.062
HR 640	McA 6	13474	02145+6631
	1982.7657	28.3	0.073
	1983.7107	33.6	0.078
	1985.8430	61.5	0.057
HR 657	Cou 79	13872	02157+2503
	1982.7577	253.0	0.154
	1982.7659	252.3	0.159
	1983.0663	253.4	0.166
	1983.7107	247.5	0.159
	1984.0630	245.4	0.151
ADS 1729	A 2013	13959	02158+0638
	1982.7577	127.1	0.294
	1983.7131	123.4	0.323
	1985.8538	117.7	0.390
+40 0476	Cou 1670	14137	02183+4120
	1983.7131	49.6	0.149
	1984.7045	48.6	0.144
	1985.8486	51.7	0.148
ADS 1763	Egg 2 Aa	14189	02186+4017
	1985.8486	106.0	0.112
+69 0144	MLR 377	14382	02231+7021
	1983.0663	152.5	0.565
	1983.7107	153.4	0.563
	1984.9967	153.2	0.586
	1985.8541	152.6	0.586
ADS 1913	A 660	------	02314+4234
	1983.0663	309.6	0.470
	1983.7131	310.5	0.458
ADS 1865	A 2329	15285	02277+0426
	1982.7577	270.0	0.372
	1983.0663	273.5	0.402
	1983.7131	276.3	0.427
	1985.8375	288.0	0.475
HR 719	Kui 8	15328	02280+0158
	1982.7577	33.9	0.494
	1982.7659	33.6	0.496
	1983.0663	33.7	0.483
	1983.7131	35.4	0.490
	1984.0575	35.0	0.489
	1984.9967	35.0	0.490
	1985.8375	34.8	0.499
ADS 1860	CHARA 6 Ap	15089	02290+6724
	1982.7576	173.5	0.496
	1985.8540	160.4	0.414
ADS 1938	STT 42 AB	15703	02333+5218
	1982.7604	282.2	0.149
	1982.7657	282.2	0.159
	1983.0663	281.3	0.160
	1983.7107	282.6	0.153
	1984.7046	284.0	0.147
	1985.8540	284.5	0.142

TABLE IV. (continued)

+79 0075	MLR 449		15416	02361+7944
		1983.0663	192°9	0"255
		1983.7107	195.0	0.267
		1985.8541	195.5	0.266
HR 763	McA 7		16234	02366+1226
		1983.7107	143.6	0.084
		1983.7159	142.9	0.093
		1984.0575	131.3	0.058
		1985.8376	130.6	0.063
ADS 1992	A 1278		16283	02383+4604
		1983.7133	160.5	0.112
		1984.7046	158.1	0.117
		1985.8540	154.8	0.119
ADS 2005	A 450		16453	02384-0125
		1983.7131	198.7	0.354
		1985.8539	196.6	0.357
ADS 1985	STF 278		16096	02389+6918
		1983.0663	34.5	0.495
		1983.7107	37.5	0.504
		1984.7070	37.0	0.502
		1985.8541	37.3	0.500
HR 781	Fin 312		16620	02396-1153
		1982.7578	235.3	0.097
		1982.7659	239.1	0.086
		1983.0471	273.1	0.104
		1983.7131	59.4	0.100
		1984.0575	92.7	0.120
		1985.8539	140.0	0.071
ADS 2028	A 1928		16619	02398-0009
		1982.7577	238.6	0.199
		1983.0663	238.8	0.199
		1983.7131	245.1	0.205
		1985.8539	255.1	0.174
ADS 2044	See 19		16753	02405-2408
		1984.7070	291.9	0.299
+38 0536	Cou 1371		------	02409+3905
		1985.8540	305.2	0.067
+40 0568	Cou 1511		16656	02415+4053
		1982.7605	66.6	0.152
		1982.7659	67.0	0.141
		1983.7131	58.9	0.133
		1984.7046	50.4	0.115
		1985.8540	31.2	0.103
HR 788	McA 8		16739	02422+4012
		1982.7659	166.7	0.049
		1983.7131	151.4	0.056
		1984.0576	94.6	0.038
		1984.0602	95.9	0.047
		1984.7046	143.8	0.051
		1985.8376	106.1	0.048
HR 793	μ Ari		16811	02424+2000
		1982.7659	105.3	0.052
+43 0576	CHARA 7		17245	02475+4416
		1984.0576	104.1	0.159
ADS 2159	McA 10 Aa		17573	02500+2716
		1984.7046	1.8	0.122
+01 0502	Vou 36		17780	02513+0141
		1983.7131	9.1	0.386
		1985.8375	9.3	0.386
ADS 2185	A 2906 AB		17743	02529+5300
		1983.0636	146.0	0.158
		1983.7133	136.6	0.150
		1985.8540	136.0	0.164
ADS 2185	STF 314 AB,C		17743	02529+5300
		1982.7576	309.8	1.563
		1983.0636	310.0	1.577
		1983.7133	310.0	1.543
		1984.0520	310.0	1.531
		1985.8540	309.9	1.552
ADS 2200	Bu 524 AB		17904	02537+3820
		1982.7605	295°0	0"183
		1982.7659	294.2	0.195
		1983.0636	293.1	0.198
		1983.7131	289.8	0.191
		1984.0521	288.4	0.189
		1985.8378	279.0	0.190
HR 854	τ Per		17878	02543+5245
		1982.7657	92.7	0.053
		1985.8378	99.8	0.067
+59 0567	MLR 520		17911	02552+5950
		1983.7133	354.2	0.121
ADS 2246	Bu 1173 AB		18442	02586+2408
		1983.0635	85.0	0.210
		1983.7131	86.3	0.219
		1984.0521	85.8	0.220
		1985.8403	86.7	0.226
ADS 2253	Bu 525		18484	02589+2137
		1982.7549	258.7	0.493
		1982.7577	258.9	0.493
		1983.0635	259.3	0.488
		1984.0521	259.7	0.492
		1984.7070	260.3	0.498
		1984.9967	260.3	0.497
		1985.8403	260.3	0.506
ADS 2257	STF 333 AB		18519-0	02592+2120
		1982.7550	208.1	1.432
		1982.7577	208.1	1.433
		1983.0635	207.5	1.430
		1984.7070	209.1	1.415
		1984.9967	208.9	1.404
		1985.8350	208.6	1.416
ADS 2271	A 1529		18549	03006+4753
		1983.7133	165.9	0.177
		1984.0520	166.4	0.179
		1985.8378	170.3	0.180
ADS 2276	A 827		18424	03024+7236
		1983.0636	252.4	0.221
		1983.7133	251.2	0.225
HR 915	γ Per		18925	03048+5330
		1982.7578	64.8	0.237
		1982.7660	64.7	0.240
		1983.0471	65.6	0.243
		1983.7107	65.9	0.247
		1983.7133	65.8	0.246
		1984.0602	65.3	0.245
		1985.0049	65.3	0.247
		1985.8378	65.0	0.239
ADS 2336	STF 346 AB		19134-5	03055+2515
		1982.7609	62.7	0.214
		1983.0635	64.5	0.221
		1983.7131	64.6	0.228
		1984.0521	64.2	0.230
		1985.8403	65.2	0.248
+61 0520	MLR 35		18990	03062+6146
		1983.7133	339.2	0.215
		1985.8431	338.9	0.220
ADS 2334	Bu 1175		19091-2	03062+4342
		1983.7131	274.5	0.606
		1985.8378	274.2	0.613
HR 952	CHARA 8		19789	03114+1303
		1982.7632	24.2	0.533
+17 0515	Cou 359		------	03143+1821
		1983.7134	171.2	0.162
		1985.8403	171.2	0.164
ADS 2440	Bu 84		20319	03161-0555
		1982.7634	10.5	0.940
		1985.8351	11.8	0.950

TABLE IV. (continued)

ADS 2436	STT 52 AB	20104	03175+6539
	1982.7578	72.4	0.456
	1983.0636	73.6	0.435
	1983.7133	72.9	0.456
	1984.7070	72.2	0.455
	1984.9967	71.9	0.455
	1985.8378	71.5	0.461
ADS 2463	See 23	20610	03184-2231
	1982.7632	62.1	0.233
	1983.0664	66.9	0.209
HR 1005	Cou 259	20756	03212+2109
	1983.7134	234.4	0.732
GL 140	Wor 4	------	03241+2348
	1983.7134	349.2	1.999
	1985.8431	347.9	2.046
+28 0532	CHARA 9	21242	03266+2843
	1985.8431	63.0	0.432
HR 1036	CHARA 10	21335	03271+1845
	1985.8403	109.4	0.076
+19 0537	Cou 260	21437	03280+2028
	1982.7632	22.5	0.217
	1983.0636	23.3	0.220
	1983.7134	23.7	0.219
	1984.0521	22.9	0.221
	1985.8431	23.1	0.223
ADS 2538	A 980	21203	03283+6015
	1983.0471	21.4	0.249
	1983.7133	19.8	0.249
	1985.8431	14.1	0.261
ADS 2563	STF 389 AB	21427	03301+5922
	1982.7578	70.5	2.663
ADS 2616	STF 412 AB	22091	03345+2428
	1982.7609	4.1	0.586
	1983.0636	2.4	0.581
	1983.7134	4.5	0.580
	1984.0521	3.7	0.581
	1984.7072	3.7	0.586
	1984.9967	3.6	0.586
	1985.8351	2.7	0.589
ADS 2628	Bu 533	22195	03356+3141
	1982.7609	43.5	1.082
	1983.7134	44.4	1.070
	1984.7072	44.4	1.068
	1984.9967	44.1	1.061
	1985.8433	43.6	1.078
ADS 2630	A 1535	22193	03361+4221
	1983.7134	315.0	0.583
	1984.0521	315.1	0.586
	1984.7072	316.3	0.594
	1984.9967	316.3	0.594
	1985.8433	317.0	0.609
ADS 2668	STF 425	22692	03400+3408
	1982.7605	73.5	1.942
	1985.8541	72.3	1.962
+31 0637	Cou 691	------	03423+3141
	1983.7134	91.3	0.138
	1984.0521	91.0	0.120
	1985.8405	91.7	0.110
+23 0496	CHARA 11	23157	03437+2339
	1983.7134	173.1	0.232
+23 0512	Cou 560	23387	03456+2420
	1982.7609	0.8	0.242
	1983.7134	1.3	0.238
	1984.0521	0.5	0.241
	1984.9996	1.6	0.243
	1985.8405	0.4	0.238
+23 0523	CHARA 12	23489	03465+2415
	1983.7134	51.6	0.230
ADS 2765	STT 62	23406	03488+6445
	1983.7133	310.7	0.311
	1984.0521	310.9	0.329
	1985.8405	314.0	0.328
ADS 2799	STT 65	23985	03504+2536
	1984.0521	209.6	0.492
	1984.9998	210.2	0.474
	1985.8351	210.4	0.448
HR 1199	Kui 15	24263	03519+0633
	1982.7632	208.8	0.647
	1982.7660	208.6	0.645
	1983.0472	208.9	0.647
	1984.0521	209.3	0.640
	1984.7072	209.3	0.646
	1984.9967	209.2	0.646
	1985.8351	208.4	0.656
ADS 2911	Hu 27	25034	03591+0948
	1984.0521	296.6	0.295
	1984.9996	302.5	0.305
	1985.8433	300.0	0.302
ADS 2928	A 1937	25248	04008+0505
	1985.8433	200.5	0.134
+19 0662	CHARA 13	25811	04063+1952
	1985.8406	66.1	0.074
ADS 3000	Hu 1363	26087	04069-2200
	1983.0636	115.2	0.412
	1984.7072	117.0	0.426
+33 0795	Cou 1082	25976	04081+3407
	1984.0522	61.8	0.290
	1985.8405	60.5	0.285
ADS 3007	A 998	25987	04089+4614
	1983.0472	266.4	0.177
	1983.0637	268.3	0.170
	1984.0521	265.3	0.169
	1985.8405	261.0	0.165
ADS 3032	A 469	26294	04094-0756
	1983.0636	105.2	0.146
	1985.8406	109.8	0.166
+42 0904	Cou 1702	26139	04100+4235
	1985.8405	123.5	0.167
	1985.8488	124.6	0.175
ADS 2963	STF 460	25007-8	04101+8042
	1982.7632	114.1	0.785
	1983.0472	114.4	0.777
	1984.0521	114.9	0.762
	1984.7072	116.5	0.770
	1985.8351	116.7	0.775
+31 0718	Cou 880	26385	04117+3133
	1984.7072	45.5	0.694
	1984.9968	45.1	0.687
	1985.8406	44.3	0.700
+23 0635	CHARA 14	284163	04119+2338
	1985.8406	86.3	0.138
Ross 29	CHARA 15	------	04120+5016
	1982.7579	77.2	0.989
	1983.0637	153.1	1.219
ADS 3053	STT 74	26547	04123+0939
	1984.0522	276.2	0.274
	1984.0603	277.0	0.274
	1984.7072	275.4	0.262
	1984.9968	275.8	0.256
	1985.8488	275.8	0.246
ADS 3064	A 1938	26690	04136+0743
	1982.7551	356.8	0.073
	1982.7661	356.5	0.066
	1984.0522	143.1	0.097
	1984.0603	142.6	0.094

TABLE IV. (continued)

HR 1331	McA 14 Aa	27176	04185+2135
	1982.7550	191°8	0″134
	1982.7579	192.6	0.136
	1982.7605	190.4	0.132
	1982.7633	192.9	0.138
	1982.7661	193.4	0.131
	1983.0472	186.2	0.133
	1983.0637	187.2	0.150
	1983.7108	182.1	0.146
	1983.7135	179.6	0.148
	1984.0522	175.0	0.145
	1984.0576	174.8	0.145
	1984.0603	172.7	0.135
	1984.9998	160.5	0.138
	1985.8378	145.7	0.114
	1985.8406	144.5	0.120
	1985.8541	145.7	0.120
ADS 3105	STT 75	26882	04186+6029
	1983.0472	178.2	0.413
	1984.0521	179.7	0.403
	1985.8405	178.7	0.405
ADS 3135	STT 79	27383	04187+1632
	1982.7551	109.2	0.229
	1982.7606	109.0	0.221
	1982.7661	110.1	0.227
	1983.0472	111.2	0.222
	1983.7162	123.3	0.186
	1984.0522	130.4	0.173
	1984.0576	132.2	0.173
	1985.8378	178.6	0.147
	1985.8406	177.5	0.149
	1985.8488	177.9	0.148
ADS 3159	Bu 744 AB	27710	04215-2544
	1983.0500	140.6	0.589
	1983.7162	142.2	0.570
	1984.7072	143.9	0.567
	1984.9968	143.5	0.539
ADS 3169	STT 82 AB	27691	04228+1504
	1984.7072	355.2	1.303
	1984.9968	355.0	1.296
HR 1375	CHARA 16	27742	04235+2059
	1985.8514	9.4	0.182
ADS 3172	STT 80	27650	04236+4226
	1982.7579	158.6	0.356
	1983.0472	158.2	0.361
	1984.0522	157.9	0.349
	1985.8406	156.6	0.348
ADS 3182	Hu 304	27820	04239+0928
	1982.7551	67.3	0.207
	1982.7633	67.7	0.207
	1983.0500	67.9	0.203
	1983.7162	70.9	0.193
	1984.0522	71.7	0.187
	1984.0604	72.3	0.187
	1985.8488	78.1	0.162
ADS 3191	Bu 1235	27832	04245+2245
	1983.0474	59.8	0.330
	1983.7162	60.5	0.334
	1984.0522	60.8	0.333
	1985.8379	62.3	0.313
	1985.8514	60.3	0.327
ADS 3210	Bu 1185	27989	04256+1852
	1982.7579	7.5	0.109
	1982.7606	8.3	0.113
	1982.7661	6.4	0.104
	1983.0499	5.5	0.114
	1985.8406	229.8	0.068
HR 1391	Fin 342 Aa	27991	04256+1557
	1982.7661	209°8	0″052
	1983.0474	191.5	0.092
	1983.7108	169.7	0.093
	1983.7135	170.8	0.074
	1984.0522	159.1	0.086
	1984.0577	159.6	0.088
	1984.0604	157.4	0.081
	1985.8379	111.4	0.093
	1985.8406	112.2	0.096
ADS 3230	Bu 311	28312	04269-2405
	1983.0500	119.2	0.467
	1983.7162	118.7	0.457
	1984.0577	120.6	0.467
	1984.7072	120.2	0.465
	1985.8351	121.3	0.468
ADS 3228	Bu 1186	28217	04275+1113
	1983.0500	131.7	0.221
	1983.7162	131.4	0.207
	1984.0522	130.5	0.205
	1984.7072	129.5	0.201
	1984.9968	128.9	0.199
	1985.8488	126.6	0.194
ADS 3247	Bu 184	28396	04279-2130
	1983.0500	251.8	1.720
HR 1411	McA 15	28307	04286+1557
	1983.7135	356.6	0.148
	1984.0522	355.4	0.164
	1984.0577	354.6	0.165
	1985.8379	353.7	0.216
	1985.8406	353.1	0.217
ADS 3248	Hu 1080	28363	04290+1610
	1982.7551	260.7	0.402
	1982.7606	260.8	0.400
	1982.7661	260.7	0.404
	1983.0500	260.8	0.406
	1984.0522	260.7	0.424
	1984.0577	261.0	0.421
	1985.8406	259.8	0.451
+17 0735	Cou 567	28436	04298+1741
	1983.7162	23.3	0.152
	1984.0522	22.5	0.149
-24 2401	RST 2347	28845	04318-2406
	1983.0500	327.6	0.194
ADS 3283	A 1839	------	04324+3850
	1983.7163	271.6	0.604
+14 0721	CHARA 17	285931	04340+1510
	1985.8514	38.6	0.147
ADS 3317	CHARA 18 Aa	29140	04357+1010
	1985.8488	16.4	0.104
ADS 3326	A 1840 AB	------	04361+0813
	1983.0500	112.1	0.178
	1985.8459	103.0	0.166
ADS 3329	STT 86	29193	04366+1945
	1983.0503	16.8	0.460
	1983.7162	17.0	0.451
	1984.0548	16.2	0.451
	1984.7072	16.0	0.451
	1985.8434	14.8	0.452
HR 1481	Kui 18	29503	04382-1418
	1982.7634	138.0	0.349
	1983.0500	141.1	0.359
ADS 3371	Bu 1044	29562	04398+1632
	1983.0503	211.1	0.667
	1985.8434	212.4	0.649
ADS 3358	Bu 1295 AB	29316	04399+5329
	1983.7163	134.2	0.182
	1984.0522	133.2	0.175
	1984.7072	129.4	0.162
	1984.9968	127.3	0.155
	1985.8434	120.6	0.136
ADS 3358	STF 566 AC	29316	04399+5329
	1984.9968	221.3	0.728
	1985.8434	220.7	0.727

TABLE IV. (continued)

ADS 3387	A 2353	29727	04426+1643
	1983.0503	154°9	0.169
	1983.7162	160.0	0.164
	1985.8434	162.4	0.165
HR 1497	McA 16	29763	04422+2257
	1982.7551	4.8	0.185
	1982.7633	4.1	0.186
	1982.7661	5.4	0.186
	1983.0474	2.1	0.187
	1983.7163	357.7	0.184
	1984.0524	354.6	0.187
	1985.8380	340.1	0.193
−21 0953	Don 75	29961-2	04425−2059
	1983.0500	77.1	0.168
ADS 3391	A 1013	29606	04432+5932
	1985.8434	58.9	0.107
+39 1054	Cou 1524	29911	04445+3953
	1982.7579	196.1	0.178
	1982.7660	196.1	0.176
	1983.0664	195.1	0.190
	1985.8434	197.8	0.184
+42 1045	Cou 2031	30090	04465+4220
	1985.8434	311.0	0.054
ADS 3445	A 2	------	04466−0437
	1985.8435	178.7	1.524
HR 1528	CHARA 19	30453	04493+3235
	1984.0576	147.8	0.041
ADS 3465	A 2621	30636	04496+0213
	1983.0502	75.4	0.150
	1985.8459	80.4	0.150
+14 0770	CHARA 20	30712	04506+1505
	1985.8459	109.6	0.072
ADS 3475	Bu 883 AB	30810	04512+1104
	1982.7551	69.6	0.243
	1982.7633	70.0	0.242
	1983.0502	73.4	0.235
	1984.0549	85.5	0.219
ADS 3483	Bu 552 AB	30869	04518+1339
	1982.7606	118.6	0.261
	1983.0503	119.9	0.264
	1984.0549	133.3	0.298
	1985.8434	146.6	0.346
[illegible]	RST 5501	31297	04545−0313
	1982.7634	45.9	0.285
	1982.7661	45.7	0.289
	1983.0502	45.5	0.287
	1984.0549	45.0	0.280
	1985.8489	42.0	0.272
ADS 3558	A 2624	31622	04573+0100
	1985.8435	304.6	0.319
ADS 3588	Bu 314 AB	31925	04592−1622
	1982.7634	160.5	0.249
	1983.0500	160.3	0.277
	1984.0604	156.3	0.321
ADS 3573	A 1303	31578	04599+5328
	1984.0524	314.3	0.206
	1985.8434	311.6	0.204
	1985.8489	311.4	0.199
+69 0288	MLR 399 AB	31264	05001+6958
	1985.8433	168.6	0.259
ADS 3608	A 1844	32092	05017+2640
	1985.8434	9.7	0.323
ADS 3662	A 481	32622	05043−0602
	1983.0500	302.5	0.447
	1985.8514	300.9	0.454
+21 0754	Cou 154 AB	32481	05044+2139
	1983.0503	308.2	0.253
	1985.8516	306.5	0.254
HR 1589	STT 89	31590	05046+7404
	1982.7633	297.9	0.467
	1982.7660	297.9	0.465
	1984.0524	298.1	0.451
	1984.9969	298.5	0.454
	1985.8407	298.0	0.458
ADS 3659	A 1023	32416	05054+4655
	1983.0637	60°0	0″353
	1984.0524	62.5	0.331
	1985.8516	61.9	0.331
ADS 3672	STT 95	32642	05055+1948
	1982.7634	303.3	0.923
	1983.0503	303.4	0.918
	1984.0549	302.7	0.913
	1984.7073	303.0	0.915
	1984.9969	302.8	0.910
	1985.8351	301.6	0.900
+22 0818	STT 97	32641	05056+2304
	1982.7634	152.0	0.354
	1983.0503	152.5	0.348
	1984.0524	152.1	0.347
	1985.8516	151.1	0.353
+22 0829	Cou 155	32864	05072+2224
	1985.8516	325.0	0.244
ADS 3711	STT 98	33054	05074+0830
	1982.7607	12.8	0.639
	1983.0638	11.2	0.631
	1984.7073	6.2	0.636
	1984.9969	5.7	0.624
	1985.8516	2.5	0.632
+37 1053	Cou 1531	32949	05085+3755
	1982.7607	89.9	0.329
	1983.0503	87.5	0.331
	1985.8516	84.8	0.320
ADS 3728	A 2636	33236	05089+0313
	1982.7634	154.5	0.260
	1985.8516	156.2	0.266
ADS 3748	A 484	33507	05103−0735
	1985.8514	150.5	0.096
ADS 3734	STF 644	33203	05104+3718
	1982.7606	222.5	1.602
	1983.0503	222.4	1.599
	1985.8516	222.6	1.597
ADS 3755	Bu 885	33546	05109−0146
	1983.0638	195.4	0.584
	1984.7073	197.1	0.594
	1984.9969	197.1	0.587
	1985.8516	197.0	0.598
ADS 3767	Hu 33	33647	05117+0031
	1982.7634	10.4	0.100
	1985.8516	7.2	0.108
ADS 3764	STF 652	33646	05118+0102
	1985.8542	181.0	1.607
ADS 3799	STT 517 AB	33883-4	05134+0158
	1982.7634	235.1	0.512
	1983.0638	235.9	0.501
	1984.7073	236.4	0.522
	1984.9969	236.3	0.523
	1985.8516	236.0	0.537
HR 1708	α Aur Aa	34029	05167+4601
	1983.0474	192.2	0.047
	1984.0524	11.3	0.047
	1984.0604	0.6	0.043
	1985.8542	57.3	0.053
+39 1272	Cou 2037	34807	05219+3934
	1982.7607	140.3	0.348
	1983.0503	140.6	0.346
	1985.8516	140.1	0.352
ADS 3991	WNC 2 A,BC	35317	05239−0053
	1983.0692	159.3	2.[illegible]50
+32 0966	Cou 1090	35132	05240+3238
	1983.0504	230.8	0.235
	1985.8516	229.8	0.234
ADS 4002	Da 5 Aa,B	35411	05244−0224
	1984.9969	78.4	1.638
	1985.8542	77.6	1.660
ADS 3997	A 2703	35365	05246+0910
	1985.8516	104.6	0.223

TABLE IV. (continued)

ADS 4020	A 848	35548	05255-0033
	1982.7634	158°2	0"207
	1985.8516	161.1	0.214
ADS 4078	Da 6	36058	05290-0318
	1985.8516	200.9	0.136
ADS 4072	Hu 217	35921	05297+3523
	1983.0503	253.1	0.608
	1985.8516	253.6	0.602
-01 0918	RST 4781	36219	05301-0145
	1983.0638	197.9	0.376
	1985.8516	199.6	0.396
ADS 4115	STF 728	36267	05307+0556
	1984.7073	49.4	0.985
	1985.8516	49.4	1.005
ADS 4123	STF 729 AB	36351	05312+0317
	1984.7073	28.4	1.802
	1984.9969	28.6	1.809
	1985.8542	28.0	1.835
ADS 4134	Hei 42 Aa	36486	05320-0018
	1982.7552	141.3	0.224
	1982.7634	141.5	0.224
	1983.0638	141.6	0.226
	1984.0605	140.2	0.230
	1985.8542	139.3	0.242
ADS 4076	A 1034	35598	05325+7049
	1983.0503	144.4	0.711
	1985.8517	143.0	0.735
HR 1891	Fin 345	37016	05353-0425
	1983.0665	89.9	0.343
ADS 4208	STF 749 AB	37098	05372+2656
	1982.7607	326.5	1.089
	1983.0692	326.2	1.100
	1984.7073	326.3	1.076
	1984.9969	326.0	1.075
	1985.8352	325.3	1.091
+43 1315	CHARA 21	36948	05373+4404
	1985.8407	60.8	0.125
ADS 4203	A 1562	36928	05373+4339
	1983.0665	348.6	0.403
	1985.8407	350.2	0.389
+43 1315	------	36947-8	05373+4404
	1982.7607	62.9	0.145
ADS 4229	Bu 1240 AB	37269	05386+3030
	1982.7607	60.1	0.082
	1983.0475	49.8	0.094
	1985.8407	31.5	0.102
ADS 4241	Bu 1032 AB	37468	05387-0235
	1982.7552	152.3	0.245
	1982.7634	152.7	0.246
	1983.0692	150.6	0.235
	1984.0605	149.2	0.242
	1985.8544	144.6	0.246
ADS 4236	A 1564	37265	05394+4343
	1985.8407	135.9	0.143
ADS 4243	STT 112	37384	05398+3758
	1983.0665	52.2	0.831
	1985.8407	53.2	0.845
ADS 4249	Hu 825	37405	05400+3601
	1983.0665	343.9	0.389
ADS 4265	Bu 1007	37711	05411+1632
	1982.7607	239.0	0.333
	1983.0665	239.3	0.345
	1985.8352	240.1	0.331
ADS 4279	Bu 1052	37904	05417-0254
	1983.0692	20.6	0.331
	1985.8544	18.7	0.383
ADS 4299	A 494 AB	38089	05428-0649
	1983.0692	104.8	0.181
	1985.8352	124.2	0.133
ADS 4304	A 117	38068	05436+1259
	1983.0665	249.9	0.786
	1984.7073	251.8	0.782
	1985.8542	250.7	0.791
ADS 4323	STT 115 AB	38182	05445+1503
	1984.7073	119°1	0"470
	1984.9969	119.1	0.466
	1985.8542	118.1	0.466
ADS 4324	A 496	38161	05449+2620
	1983.0475	7.4	0.275
	1983.0665	4.7	0.276
	1985.8407	7.0	0.271
+28 0871	Cou 762	38153	05450+2812
	1983.0665	66.4	0.166
	1985.8407	62.2	0.176
HR 2001	McA 22	38735	05474-1032
	1983.0665	102.3	0.162
	1984.0605	111.2	0.161
	1985.8544	108.6	0.175
ADS 4390	STF 795	38710	05480+0627
	1983.0665	215.2	1.170
	1984.9969	216.7	1.151
	1985.8352	216.4	1.161
ADS 4396	A 2657	38769	05482+0137
	1983.0665	157.9	0.179
	1985.8542	167.9	0.177
ADS 4392	STT 118 AB	38670	05484+2052
	1982.7607	316.7	0.250
	1983.0665	313.9	0.237
	1985.8542	316.4	0.214
ADS 4376	STF 3115	38284	05491+6248
	1982.7634	352.0	0.859
	1983.0665	351.6	0.872
	1984.0552	351.6	0.836
	1984.7074	351.4	0.836
	1984.9971	351.2	0.836
	1985.8517	350.3	0.844
+29 1028	Cou 898	39303	05529+2907
	1985.8407	156.6	0.152
+28 0933	Cou 900	39451	05539+2857
	1985.8407	83.1	0.169
ADS 4532	Hu 1235	39924	05573+3601
	1983.0665	102.0	0.186
+24 1043	Cou 905	40132	05580+2437
	1985.8517	15.8	0.186
ADS 4562	STT 124	40369	05589+1249
	1982.7607	297.5	0.482
	1983.0665	298.0	0.496
	1985.8542	297.4	0.499
ADS 4617	A 2715 AB	40932	06024+0939
	1984.0632	283.0	0.167
	1985.8544	212.6	0.086
HR 2134	Kui 23 AB	41116	06041+2316
	1982.7635	20.9	0.101
	1983.0475	35.1	0.093
	1984.0605	113.2	0.093
	1984.0632	108.0	0.098
	1985.8380	157.4	0.204
ADS 4660	A 1951	41379	06052+0708
	1983.0667	43.2	0.433
	1985.8435	44.5	0.441
ADS 4603	STT 121	40225	06053+7400
	1984.0552	243.5	0.252
+18 1095	Cou 471	41658	06073+1848
	1983.0693	168.8	0.282
	1985.8435	166.3	0.300
+26 1082	McA 25	41600	06074+2640
	1985.8380	220.3	0.063
ADS 4696	STT 130	41541	06078+4240
	1983.0667	199.7	0.386
	1984.0551	202.0	0.392
	1985.8380	200.6	0.401
	1985.8435	201.2	0.399
ADS 4750	A 54 AB	42033	06098+2914
	1983.0667	335.2	0.527
	1985.8353	335.2	0.541
	1985.8380	336.2	0.532
	1985.8435	335.2	0.538

TABLE IV. (continued)

HR 2186	RST 3442		42443	06098-2246
		1983.0475	299°9	0″175
		1983.0667	301.1	0.168
ADS 4768	Bu 1058		42216	06105+2300
		1982.7635	238.1	0.237
		1983.0667	242.9	0.220
		1985.8407	237.1	0.229
HR 2214	Kui 24		42954	06144+1754
		1983.0693	138.5	0.492
		1984.0579	139.2	0.479
		1984.9971	139.4	0.483
ADS 4866	A 668		43362	06154-0902
		1985.8544	42.1	0.079
HR 2236	RST 5225		43358	06159+0110
		1983.0667	220.4	0.203
		1984.0579	224.4	0.215
		1985.8544	238.1	0.200
ADS 4890	Fin 331 Aa		43525	06171+0957
		1982.7552	326.5	0.071
		1983.0475	347.5	0.066
		1984.0605	254.8	0.044
		1985.8544	322.9	0.069
HR 2273	CHARA 22		44112	06197-0749
		1985.8544	55.5	0.055
ADS 4929	Bu 895 AB		43885	06200+2826
		1982.7635	124.8	0.223
		1984.0552	126.6	0.232
		1985.8407	128.5	0.242
ADS 4951	A 2719		44109	06203+0744
		1983.0667	61.1	0.445
		1984.0579	62.4	0.450
		1985.8352	63.2	0.462
ADS 4971	A 2667		44333	06214+0216
		1984.0579	172.5	0.288
		1985.8544	178.4	0.278
ADS 4950	STF 881 AB		43812	06221+5923
		1983.0665	130.3	0.682
		1984.0552	132.0	0.680
		1984.7074	132.9	0.682
		1984.9971	132.3	0.673
		1985.8407	132.5	0.691
ADS 5023	Bu 568		44953	06238-1947
		1983.0693	154.3	0.808
HR 2312	Fin 343		45050	06252+0130
		1983.0475	8.8	0.170
		1984.0579	5.7	0.159
		1985.8381	0.6	0.169
+23 1346	CHARA 23		44926	06255+2327
		1965.8408	150.9	0.104
HR 2304	McA 26		44927	06256+2320
		1985.8381	141.1	0.054
+24 1276	Cou 914		45428	06283+2441
		1983.0667	115.2	0.212
ADS 5103	BTZ Aa		45542	06289+2014
		1982.7552	135.9	0.080
		1984.0579	140.3	0.049
		1984.0634	144.8	0.055
Ross 614	GL 234		------	06294-0249
		1982.7581	215.6	0.486
+52 1088	Wor 6		------	06323+5225
		1983.0668	276.6	0.447
ADS 5218	A 506		46610	06357+2816
		1983.0667	32.3	0.250
		1984.0552	34.1	0.249
		1985.8381	34.2	0.241
ADS 5224	A 1051		45655	06367+4415
		1984.0552	224.9	0.691
		1984.7074	225.4	0.689
		1985.8408	224.5	0.687
		1985.8435	224.4	0.692
HR 2425	McA 27		47152	06383+2859
		1982.7552	356°0	0″085
		1982.7635	356.8	0.086
		1983.0475	352.5	0.092
		1984.0552	342.0	0.107
		1984.0605	340.2	0.099
		1984.0634	344.8	0.101
		1985.8381	327.7	0.132
ADS 5289	STT 152		47395	06395+2816
		1984.0552	36.8	0.863
		1984.9971	36.8	0.857
		1985.8408	36.0	0.861
ADS 5332	A 218		47812	06418+3041
		1985.8381	69.9	0.181
+70 0410	MLR 405		46979	06425+7035
		1984.0552	245.5	0.540
		1985.8407	245.2	0.549
ADS 5407	A 2825		48688	06450+1045
		1984.9998	3.8	0.190
		1985.8381	5.7	0.197
ADS 5429	Ho 238		48884	06463+1812
		1985.8353	172.4	0.361
ADS 5400	STF 948 AB		48250	06463+5927
		1983.0668	80.3	1.794
		1985.8435	79.3	1.803
+16 1273	CHARA 24		48954	06468+1646
		1983.0695	37.1	0.489
ADS 5447	STT 156		49059	06474+1812
		1983.0667	239.8	0.406
		1984.0605	238.9	0.400
		1985.8353	236.3	0.401
HR 2521	Fin 322		49643	06492-0217
		1983.0475	61.5	0.157
		1983.0667	57.0	0.155
		1984.0579	59.5	0.154
		1984.9998	58.3	0.155
		1985.8381	55.3	0.159
+36 1511	Cou 1738		49472	06502+3625
		1984.0525	101.0	0.110
		1984.9999	104.8	0.105
		1985.8409	106.2	0.111
+24 1417	Cou 768		49622	06503+2410
		1984.9999	259.7	0.078
		1985.8409	256.9	0.096
ADS 5514	STF 963 AB		49618-9	06532+5928
		1982.7634	259.3	0.270
		1983.0476	259.0	0.273
		1983.0668	259.7	0.265
		1984.0525	261.5	0.267
		1984.9999	263.6	0.263
		1985.8545	264.9	0.262
HR 2541	Cou 1877		50037	06532+3827
		1983.0475	149.0	0.502
		1984.0525	151.0	0.486
		1984.9972	152.3	0.480
		1985.8409	153.0	0.484
ADS 5557	STF 987		50700	06541-0552
		1984.9972	174.7	1.293
		1985.8435	174.3	1.314
ADS 5571	A 2833		50722	06549+1158
		1985.8408	262.9	0.058
ADS 5586	STT 159 AB		50522	06573+5825
		1983.0668	46.6	0.494
		1984.0525	47.3	0.466
		1984.9972	48.5	0.427
		1985.8545	49.3	0.394
ADS 5625	A 2681		51449	06575+0253
		1985.8381	140.9	0.298
+02 1483	CHARA 25		51566	06580+0218
		1985.8408	40.7	0.910
+65 0550	MLR 133		50452	06582+6516
		1985.8545	20.5	0.112

TABLE IV. (continued)

HR 2605	McA 28	51688	06595+2555
	1982.7635	33°5	0″082
	1984.0525	43.1	0.073
	1984.0605	40.8	0.072
	1984.9999	44.5	0.059
	1985.8544	48.5	0.064
ADS 5660	A 2461 AB	51911	06598+1557
	1983.0476	328.0	0.311
	1985.8408	326.3	0.316
ADS 5671	Bu 1022 AB	267648	07007+2716
	1985.8409	68.3	0.321
ADS 5689	STT 163 AB	52309	07011+1146
	1984.0580	57.6	0.113
	1984.9998	56.0	0.113
	1985.8408	63.1	0.120
ADS 5707	A 3042 AB	52590	07015-0942
	1985.8381	204.4	0.324
ADS 5712	Bu 573	52694	07018-1053
	1985.8544	294.5	0.854
+37 1645	McA 29	52823	07043+3734
	1983.0476	176.2	0.169
	1984.0581	179.4	0.165
	1985.8409	178.9	0.171
ADS 5814	A 3043	54336	07079-1542
	1983.0476	292.6	0.200
ADS 5857	A 2122	55118	07113-1033
	1985.8544	83.3	0.137
+20 1729	Cou 925	54985	07118+1953
	1985.8408	80.2	0.496
ADS 5866	AG	------	07123+1839
	1985.8436	194.4	0.636
ADS 5871	STF 1037 AB	55130	07128+2714
	1983.0668	318.4	1.262
	1983.0695	318.7	1.243
	1984.0581	319.3	1.207
	1984.9972	318.5	1.213
	1985.8436	317.5	1.225
ADS 5918	Bu 1023	55726	07151+2553
	1984.0525	302.7	0.438
	1985.8409	302.1	0.443
ADS 5956	A 2123 AB	56593	07171-1201
	1985.8545	149.9	0.291
+24 1600	Cou 585	56462	07181+2405
	1985.8436	154.3	0.378
ADS 5975	Hu 619 AB	56627	07202+4820
	1985.8491	1.8	0.366
ADS 5996	STF 1074 AB	57275	07205+0024
	1984.0525	168.1	0.634
	1984.9972	168.3	0.636
	1985.8436	168.1	0.642
-20 1935	DON 181	58763	07262-2024
	1983.0504	132.2	0.501
+69 0422	MLR 409	57308	07264+6929
	1985.8545	345.2	0.379
+20 1805	CHARA 26	58579	07269+2015
	1984.0607	127.1	0.030
	1985.0000	163.4	0.049
ADS 6089	McA 30 Aa	58728	07277+2127
	1983.0476	166.1	0.110
	1985.0000	166.8	0.099
ADS 6126	STF 1104 AB	59438	07294-1459
	1983.0504	14.6	1.945
ADS 6138	A 2869	59473	07305+0743
	1983.0504	26.6	0.153
	1984.0525	25.0	0.135
	1985.8545	16.9	0.129
+08 1791	CHARA 27	59604	07309+0833
	1983.0504	59.7	0.261
HR 2886	McA 32	60107	07336+1550
	1983.0505	89.8	0.195
	1984.0525	90.3	0.189
	1984.0607	90.9	0.186
	1985.0001	91.1	0.183
	1985.8491	89.5	0.183
ADS 6185	STT 175 AB	60318	07352+3058
	1983.0476	328°9	0″182
	1984.0526	329.3	0.190
	1985.8491	328.2	0.206
-25 4775	B 729	61071	07365-2520
	1983.0504	171.8	0.116
ADS 6244	Ho 245 AB	61343	07387-0127
	1983.0504	184.8	0.602
	1984.9972	185.6	0.602
	1985.8436	185.1	0.601
ADS 6245	A 535	61344	07387-0459
	1983.0504	172.1	0.357
ADS 6263	STF 1126 AB	61563	07401+0515
	1983.0504	165.0	0.941
	1985.8353	165.6	0.926
ADS 6313	A 2534 AB,C	62264	07431+0012
	1985.8353	231.1	0.817
ADS 6347	Ho 247	62720	07462+2108
	1984.0525	231.8	0.386
	1985.8409	233.3	0.397
-03 2065	RST 4375	63263	07478-0332
	1983.0504	344.3	0.121
ADS 6354	Hu 1247	62522	07479+6019
	1983.0476	291.8	0.226
	1984.0526	283.1	0.235
-19 2068	B 1077 AB	63395	07480-1924
	1983.0504	298.7	0.535
ADS 6378	WRH 15 AB	63208	07486+2309
	1984.0525	50.8	0.268
	1984.0607	50.3	0.268
	1985.8409	49.3	0.272
ADS 6405	A 2880	63799	07508+0317
	1983.0504	280.2	0.122
	1985.0000	292.7	0.102
ADS 6412	Bu 1195	63976	07513-0925
	1983.0504	90.6	0.198
ADS 6420	Bu 101	64096	07518-1352
	1983.0504	84.8	0.265
HR 3072	Fin 325	64235	07528-0526
	1983.0504	180.6	0.354
	1985.0000	184.4	0.296
	1985.8353	186.8	0.264
+24 1805	Cou 929	64704	07561+2342
	1983.0476	113.7	0.126
	1985.8409	142.8	0.135
ADS 6483	STT 185	65123	07573+0108
	1983.0504	65.1	0.179
	1985.0000	74.7	0.162
HR 3109	McA 33	65339	08017+6019
	1983.0476	282.8	0.114
	1984.0526	298.8	0.091
ADS 6538	STT 186	66176	08033+2616
	1984.9972	74.9	0.951
	1985.8436	74.4	0.965
ADS 6554	Bu 581 AB	66509	08043+1218
	1983.0476	266.6	0.544
	1985.8436	274.3	0.556
ADS 6578	A 1333	66610	08070+5407
	1983.0476	208.4	0.360
	1984.0526	208.8	0.350
	1985.8436	208.1	0.361
ADS 6623	STF 1187	67501	08095+3213
	1985.8436	26.2	2.762
ADS 6650	STF 1196 AB	68255-7	08122+1740
	1983.0476	254.1	0.673
	1984.0526	245.4	0.642
	1984.9973	236.0	0.618
	1985.0028	236.3	0.619
	1985.8353	226.3	0.601
+29 1712	Cou 1114	68254	08126+2849
	1983.0476	227.0	0.219
	1984.0526	229.1	0.221
	1985.8409	226.9	0.207

TABLE IV. (continued)

HR 3269	Fin 346		70013	08199+0357
		1983.0476	72°4	0″266
		1984.0526	72.4	0.266
		1985.8545	70.8	0.269
ADS 6762	STF 1216		70340	08214-0136
		1985.8436	280.9	0.525
ADS 6796	Hu 856		70803	08253+3723
		1984.0526	257.9	0.252
ADS 6811	A 1746 BC		71153	08267+2433
		1984.0526	154.5	0.148
-20 2538	B 2179		71581	08276-2051
		1983.0477	212.2	0.397
ADS 6828	A 551 AB		71663	08285-0230
		1984.0553	74.4	0.182
ADS 6862	I 489		72310	08315-1934
		1983.0476	5.5	0.205
		1984.0607	2.4	0.200
ADS 6914	Bu 208 AB		73752	08391-2240
		1983.0477	11.8	0.360
		1984.9973	21.0	0.548
+20 2148	Cou 47		73574	08397+2005
		1983.0476	141.6	0.515
		1984.0553	142.8	0.508
		1985.8436	141.1	0.521
+20 2159	CHARA 28		73666	08402+2001
		1983.0477	126.7	0.425
ADS 6924	A 1749		------	08412+4352
		1985.8436	106.6	0.625
ADS 6930	Bu 585		73871	08412+2028
		1984.0526	88.2	0.492
		1984.9973	87.5	0.487
		1985.8436	87.1	0.488
ADS 6993	SP AB		74874	08468+0625
		1984.0553	196.0	0.255
		1984.0608	195.7	0.259
ADS 6999	Bu 586		75098	08473-1703
		1984.0553	105.6	0.177
+00 2392	RST 5306		75012	08476+0005
		1984.0553	36.6	0.167
ADS 7012	A 2552		75207	08486+0057
		1984.0553	144.6	0.149
ADS 7039	A 2473		75470	08507+1800
		1983.0641	46.3	0.297
		1984.0553	47.3	0.305
+20 2232	Cou 773		75974	08539+1958
		1983.0641	41.8	0.206
		1984.0553	42.8	0.216
		1985.0001	43.3	0.218
ADS 7074	A 2554		76050	08539+0149
		1984.0553	20.5	0.181
ADS 7071	STF 1291 AB		75959	08542+3034
		1984.0554	313.0	1.451
		1984.9974	313.0	1.448
		1985.8436	312.2	1.471
ADS 7082	A 2131 AB		76095	08549+2613
		1983.0479	183.6	0.360
		1984.0553	188.1	0.361
		1985.0001	192.4	0.364
ADS 7067	STF 1280 AB		75632	08557+7048
		1983.0642	126.6	1.189
		1985.8436	138.8	1.089
ADS 7084	A 2132		76117	08557+4141
		1984.0554	198.7	0.171
+36 1889	Cou 1897		76595	08585+3548
		1984.0554	165.4	0.170
		1985.0001	169.0	0.165
HR 3579	Kui 37 AB		76943	09008+4148
		1984.0554	348.2	0.587
		1984.9974	335.7	0.533
ADS 7158	A 1585		77327	09036+4709
		1983.0642	280°1	0″259
		1984.0554	280.4	0.257
		1984.0609	280.8	0.257
		1985.0001	279.5	0.248
		1985.8353	278.0	0.238
HR 3650	Fin 347 Aa		79096	09123+1459
		1984.0527	141.1	0.157
		1984.0582	144.3	0.161
ADS 7284	STF 3121		79969	09180+2835
		1983.0643	203.5	0.473
		1984.0527	209.0	0.495
+19 2194	Cou 384		80082	09183+1847
		1984.0527	53.4	0.116
+77 0361	Kui 39		------	09184+7716
		1983.0642	186.5	0.764
ADS 7286	STF 1333		80024	09185+3522
		1983.0642	48.5	1.824
		1984.0582	49.9	1.811
ADS 7307	STF 1338 AB		80441	09210+3812
		1983.0642	259.0	1.024
		1984.0527	260.8	1.016
		1984.9974	262.4	1.016
ADS 7341	A 2477		81163	09245+1808
		1984.0527	332.7	0.376
HR 3750	B 2530		81809	09278-0604
		1984.3859	314.1	0.120
ADS 7390	STF 1356		81858	09285+0904
		1984.0527	33.2	0.428
		1984.0609	33.0	0.429
		1984.3777	34.4	0.429
+58 1192	MLR 549		81772	09299+5808
		1984.0526	120.3	0.223
HR 3794	Fin 349		82543	09326+0151
		1984.0527	161.6	0.162
		1984.3777	161.9	0.158
		1984.3859	162.3	0.160
ADS 7456	STF 1372		83190	09371+1614
		1984.0527	76.8	0.151
		1984.9974	80.0	0.131
ADS 7457	A 1765		83158	09379+4554
		1984.0527	185.9	0.124
+54 1323	CHARA 29		233666	09423+5328
		1983.0642	54.7	0.354
ADS 7487	MLR 323 Aa		83661	09432+6708
		1983.4196	43.9	0.277
		1984.0603	29.0	0.500
HR 3871	Fin 326		84367	09442-2746
		1984.3777	192.4	0.070
HR 3880	McA 34		84722	09474+1134
		1984.0527	229.5	0.070
		1984.3778	233.0	0.061
+21 2108	Cou 284		84739	09477+2036
		1984.0527	64.0	0.153
		1984.0555	63.9	0.154
		1984.3750	63.7	0.152
		1984.3832	63.4	0.150
HR 3889	Kui 44		85040	09498+2111
		1983.0698	209.6	0.243
		1984.0527	210.9	0.231
		1984.3750	210.8	0.231
		1984.3832	210.8	0.230
		1985.8353	206.4	0.234
ADS 7541	Ho 369 AB		85177	09512+3629
		1983.4196	100.5	0.390
		1984.0529	101.0	0.392
ADS 7545	STT 208		85235	09521+5404
		1983.0699	124.7	0.200
		1983.4196	127.2	0.193
		1984.0529	132.6	0.191
		1984.3750	135.1	0.189
		1984.3833	135.4	0.188
		1985.0084	141.0	0.182

TABLE IV. (continued)

ADS 7555 AC 5 AB		85558	09525-0806
	1984.0554	80°1	0″510
	1984.3777	79.5	0.516
ADS 7635 I 293		87556	10052-2812
	1984.0554	324.6	0.168
+34 2079 Cou 1569		87473	10059+3412
	1984.0527	80.7	0.146
HR 3973 CHARA 30		87682	10068+0537
	1984.3832	139.5	0.132
ADS 7651 Kui 48 AB		87822	10083+3137
	1983.0698	171.7	0.157
	1984.0527	175.4	0.122
	1984.3778	177.9	0.109
ADS 7662 A 2145		88021-2	10093+2020
	1983.0698	179.7	0.124
	1984.0527	177.8	0.112
	1984.0555	177.0	0.120
	1984.3750	176.9	0.108
	1984.3778	176.1	0.110
	1984.3832	175.1	0.108
+75 0403 Kui 47		------	10111+7508
	1984.3860	116.7	1.223
ADS 7674 Hu 874		88355	10117+1321
	1984.0527	288.4	0.138
	1984.3750	288.6	0.127
	1984.3778	289.6	0.125
	1984.3832	289.2	0.124
ADS 7675 Ho 44		88478	10121-0613
	1984.0554	206.9	0.515
ADS 7704 STT 215		88987	10163+1744
	1983.0698	181.5	1.347
	1984.0555	182.9	1.315
	1984.3860	182.8	1.312
	1984.9974	182.8	1.313
ADS 7769 A 2570		90361	10260+0256
	1984.0554	307.2	0.335
	1984.3832	307.1	0.337
+20 2486 Cou 292		90460	10269+1931
	1984.0527	271.3	0.098
	1984.3750	264.6	0.117
	1984.3832	264.7	0.115
ADS 7775 STT 217		90444	10270+1713
	1983.0645	142.0	0.458
	1984.0527	143.1	0.474
	1984.0610	143.1	0.470
	1984.3750	143.6	0.470
	1984.3778	141.3	0.473
ADS 7780 Hu 879		90537	10279+3643
	1983.0645	231.1	0.463
	1983.0698	230.5	0.462
	1983.4196	231.4	0.450
	1984.0529	232.0	0.437
	1984.0557	232.0	0.435
	1984.3750	232.3	0.430
	1984.3860	232.2	0.433
	1984.9974	232.9	0.413
+13 2274 CHARA 31		91498	10341+1222
	1983.4277	180.8	0.192
ADS 7844 A 2055 AB		91751	10366+4430
	1983.0671	162.0	0.329
	1984.0583	160.5	0.322
	1984.3833	162.1	0.327
ADS 7852 I 857		91955	10366-2846
	1984.3805	272.0	0.262
ADS 7896 A 2768		92749	10427+0335
	1983.0507	335.4	0.204
	1984.0529	329.5	0.214
	1984.3778	322.9	0.223
	1984.3805	323.3	0.220
	1984.3859	324.9	0.225
ADS 7915 Ho 532		------	10453+3831
	1983.4277	131.9	0.371
ADS 7929 STT 229		93457	10481+4107
	1983.0671	279°7	0″776
	1983.4277	279.3	0.766
	1984.3860	278.9	0.769
ADS 7936 STF 1476		93742	10493-0401
	1983.4277	13.3	2.265
+12 2266 CHARA 32		93993	10511+1135
	1983.4277	9.9	0.429
HR 4291 CHARA 33		95345	11006+0337
	1983.4196	33.8	0.235
	1984.3860	36.2	0.177
+29 2110 Cou 960		95342	11008+2913
	1984.3833	88.6	0.088
+30 2097 CHARA 34 Aa		95515	11018+2952
	1983.4277	102.5	0.242
ADS 8035 Bu 1077		95689	11037+6145
	1985.0029	297.0	0.775
HR 4314 Fin 47		96202	11053-2718
	1983.4277	223.7	0.090
	1984.3805	197.3	0.058
	1984.3833	200.7	0.064
ADS 8064 Hu 886		------	11088+7626
	1984.3860	169.5	1.097
LFT 771-2 GL 9351		------	11114+4327
	1983.0671	78.3	3.851
ADS 8086 Bu 220		97411	11124-1830
	1983.4169	332.4	0.310
	1984.0529	328.8	0.267
	1984.3805	328.6	0.280
	1984.3833	328.5	0.282
ADS 8092 A 1353		97455	11136+5525
	1983.0671	227.4	0.400
	1983.4167	226.4	0.387
	1984.0529	227.8	0.417
	1984.3833	227.4	0.421
ADS 8094 STF 1517		97561	11137+2008
	1983.4167	326.8	0.407
	1984.0583	327.0	0.415
	1984.3724	325.9	0.430
	1984.3833	326.2	0.424
ADS 8104 Hu 639		97773	11154+4728
	1983.0699	87.0	0.083
	1984.0529	88.2	0.083
	1984.0610	86.7	0.079
	1984.3833	85.6	0.088
+43 2096 Cou 1904		97857	11158+4227
	1983.0671	195.1	0.282
	1984.3833	198.9	0.293
ADS 8119 STF 1523 AB		98230-1	11182+3133
	1983.0673	96.7	2.655
	1983.4277	95.7	2.557
	1984.3724	91.9	2.347
ADS 8145 A 2776 AB		98914	11231+0408
	1983.0507	99.8	0.152
	1984.3778	103.8	0.128
	1984.3801	102.0	0.132
-00 2442 RST 4944		99651	11279-0142
	1983.0508	293.6	0.242
	1983.0699	293.8	0.247
	1984.0529	293.5	0.246
	1984.3805	292.0	0.237
	1984.3833	291.7	0.241
ADS 8189 STT 234		100018	11308+4117
	1983.4167	124.9	0.291
	1984.0529	129.7	0.300
	1984.3751	129.9	0.305
	1984.3833	130.3	0.307
ADS 8198 Hu 1134		100235	11322+3615
	1984.3833	125.9	0.057
ADS 8197 STT 235		100203	11324+6105
	1983.4169	241.6	0.451
	1984.0529	247.4	0.469
	1984.0557	247.6	0.468
	1984.3750	250.2	0.477

TABLE IV. (continued)

ADS 8210	Hu 727	233841	11332+4928
	1984.0530	23°2	1″161
ADS 8231	STF 1555 AB	100808	11363+2747
	1983.0482	143.1	0.578
	1983.4279	142.9	0.573
	1984.3726	143.3	0.579
	1984.9977	143.5	0.587
	1985.4894	143.4	0.599
ADS 8249	STF 1559	101150	11388+6421
	1983.0508	322.6	1.957
	1984.9977	322.5	1.929
−03 3167	RST 5524	101969	11441−0448
	1983.4141	354.9	0.340
+22 2411	CHARA 35	------	11516+2207
	1983.4279	142.1	0.176
−04 3155	CHARA 36	103036	11518−0546
	1983.4277	55.2	0.234
ADS 8347	A 1777 AB	103483	11551+4629
	1983.4141	157.2	0.107
	1984.0530	162.2	0.105
	1984.3751	164.2	0.107
	1984.3834	163.9	0.103
	1985.4894	167.9	0.109
ADS 8387	A 1088	104288	12005+6912
	1983.0508	280.0	0.140
	1983.4141	281.2	0.140
	1984.0530	282.4	0.130
	1984.3834	284.8	0.131
	1985.4812	288.9	0.127
+48 1992	Cou 1752	------	12018+4728
	1984.0530	71.7	0.172
	1984.3834	69.1	0.162
ADS 8419	STF 3123 AB	105122	12061+6842
	1983.0508	319.7	0.140
	1983.0699	317.3	0.143
	1983.4141	314.0	0.142
	1984.0530	310.4	0.143
	1984.0557	310.8	0.146
	1984.3726	305.3	0.159
	1984.3778	306.7	0.149
	1984.3834	307.1	0.147
	1985.4894	296.3	0.150
Gl 9392	Wor 22	------	12101+0526
	1984.3861	318.1	1.439
Gl 9392	Wor 22 AC?	------	12101+0526
	1984.3861	69.9	0.363
ADS 8463	B 221	106271	12137−2719
	1983.4141	108.0	0.350
ADS 8481	Bu 920	106612	12158−2321
	1984.9976	300.2	1.604
ADS 8486	STF 1621	------	12160+0539
	1983.4141	0.4	0.607
HR 4668	CHARA 37	106760	12165+3304
	1983.0482	171.6	0.248
HR 4689	McA 37	107259	12199−0040
	1983.0482	346.3	0.149
	1983.0699	348.2	0.140
	1983.4141	352.5	0.146
	1983.4169	351.7	0.140
	1984.0529	2.3	0.136
	1984.0557	2.4	0.137
	1984.0583	2.9	0.138
	1984.0612	2.2	0.132
	1984.3726	7.2	0.135
	1984.3751	7.0	0.132
	1985.0004	18.1	0.120
	1985.4812	30.6	0.112
ADS 8525	B 227	107539	12216−2716
	1983.4141	156.5	0.150
ADS 8535	STT 249 AB	107922	12238+5410
	1983.0508	267°4	0″406
	1983.4141	266.9	0.411
	1984.0530	266.5	0.407
	1984.3726	266.6	0.393
	1984.3778	266.0	0.401
	1985.4812	266.0	0.415
ADS 8540	STT 250	108005	12244+4306
	1983.0482	343.6	0.376
	1983.4141	342.5	0.372
	1985.4812	345.0	0.374
ADS 8539	STF 1639 AB	108007	12244+2535
	1983.0482	326.0	1.539
	1983.4279	325.3	1.521
ADS 8551	A 78	108320	12267−0535
	1983.4141	141.5	0.179
	1984.3862	142.5	0.160
ADS 8555	B 228	108410	12274−2843
	1984.3779	138.5	0.222
HR 4789	WRH	109485	12348+2238
	1983.0699	9.4	0.327
	1983.4169	11.4	0.320
	1984.0531	10.3	0.319
	1984.0613	10.1	0.314
	1984.3727	9.8	0.305
	1985.4894	8.2	0.303
+27 2158	Cou 596	110297	12409+2708
	1983.0699	194.5	0.125
	1984.3834	193.5	0.099
	1985.4813	193.3	0.090
ADS 8630	STF 1670 AB	110379−0	12417−0127
	1983.4279	292.6	3.461
HR 4891	CHARA 38	111998	12532−0333
	1984.3752	164.0	0.442
ADS 8708	STT 256	112398	12564−0057
	1983.4279	95.8	0.955
	1984.3727	95.0	0.971
	1984.3861	95.5	0.968
	1984.9978	95.6	0.960
+09 2696	Fin 380	112503	12572+0818
	1983.0699	150.4	0.112
	1983.4199	152.6	0.117
	1984.0531	152.9	0.118
	1984.3727	154.1	0.136
	1984.3779	153.2	0.124
	1984.3834	154.8	0.125
	1985.4813	155.5	0.138
	1985.4894	153.0	0.138
GL 491	B 2541	112758	12591−0951
	1983.4280	109.9	0.768
ADS 8727	CHARA 39 Aa	112846	12597−0348
	1984.0558	19.5	0.107
	1984.3779	32.5	0.103
	1984.3862	28.9	0.092
ADS 8757	Bu 341	113415	13038−2035
	1983.4304	311.9	0.796
	1984.0531	311.8	0.790
ADS 8759	Bu 929	113459	13039−0340
	1983.4280	202.1	0.686
	1984.0558	201.7	0.685
	1984.3779	201.7	0.687
	1984.3861	201.9	0.687
	1984.9978	201.8	0.680
	1985.4894	201.4	0.681
GL 497	Wor 23	------	13048+5555
	1983.0508	151.6	1.448
	1983.4279	141.6	0.687
+61 1335	MLR 154	113810	13052+6052
	1984.0530	86.8	0.069
ADS 8785	A 1605	234012	13069+5200
	1984.3862	165.9	0.938

TABLE IV. (continued)

ADS 8801	McA 38 Aa	114330	13100-0532
	1983.0699	326°4	0″481
	1984.0532	328.7	0.454
	1984.3752	327.9	0.466
	1984.3807	327.4	0.459
	1985.4840	327.9	0.472
ADS 8804	STF 1728 AB	114378-9	13100+1731
	1983.0699	191.8	0.627
	1983.4199	193.0	0.610
	1984.0558	193.1	0.613
	1984.0586	193.0	0.609
	1984.3727	193.0	0.612
	1984.3807	193.2	0.611
	1985.0031	192.8	0.600
	1985.4813	192.9	0.588
HR 4978	Fin 305	114576	13117-2633
	1984.3779	116.3	0.100
ADS 8814	STT 261	114723	13120+3205
	1983.0508	339.5	2.325
ADS 8831	Fin 297 AB	114993	13145-2417
	1983.4332	134.9	0.183
	1984.3779	136.8	0.187
ADS 8843	STT 263	------	13167+5034
	1984.3864	134.4	1.820
HR 5014	Fin 350	115488	13175-0041
	1983.0701	349.1	0.078
	1983.4332	355.3	0.089
	1984.0532	1.2	0.119
	1984.3752	5.9	0.109
	1984.3807	5.6	0.110
	1984.3835	6.2	0.111
	1985.4840	14.2	0.122
ADS 8863	A 2166	115955	13202+1747
	1983.0510	190.3	0.113
	1983.0701	191.9	0.102
ADS 8864	STF 1734	115995	13207+0257
	1983.0510	178.6	1.100
	1983.4332	178.4	1.087
	1984.3779	178.7	1.080
	1984.3807	178.6	1.076
ADS 8887	HO 260	116495	13236+2914
	1984.0558	74.3	1.180
	1985.4840	74.9	1.230
ADS 8903	STT 267	117173	13253+7559
	1984.3754	15.3	0.100
ADS 8901	A 1609 AB	116878	13258+4430
	1985.4866	284.0	0.219
ADS 8904	AG 187	117009	13272+2028
	1984.0558	123.7	1.588
	1985.4840	123.5	1.620
+31 2500	Wor 24	------	13320+3109
	1984.3781	302.7	0.180
	1984.3807	302.3	0.174
VYS 144 AB	VW Com	------	13328+1649
	1983.0510	37.9	3.065
	1984.3865	39.6	3.060
ADS 8939	STT 269 AB	117902	13328+3454
	1983.0511	243.3	0.140
	1983.0701	242.1	0.130
	1984.0532	255.8	0.127
	1984.3728	259.0	0.114
	1984.3754	248.0	0.104
	1984.3835	247.7	0.102
	1985.4840	254.0	0.080
ADS 8954	Bu 932 AB	118054	13348-1313
	1983.4304	50.9	0.342
	1984.0558	51.0	0.344
	1984.3727	51.0	0.343
	1984.3807	51.1	0.345
ADS 8964	AG 190	------	13357+4939
	1984.3864	12.8	2.540
ADS 8980	ES 608	------	13380+4808
	1984.3864	306.1	2.273
ADS 8987	Bu 612 AB	118889	13396+1044
	1983.0510	202°3	0″276
	1983.0701	201.1	0.280
	1984.0532	208.0	0.285
	1984.3727	207.9	0.284
	1984.3752	208.7	0.290
	1984.3835	209.1	0.289
	1985.4813	213.8	0.299
ADS 8988	Hu 897	------	13400+3759
	1984.0559	30.7	0.378
ADS 8994	Fin 352 AB	119086	13415-2327
	1983.4307	323.0	0.184
	1984.3779	320.1	0.177
	1904.3862	321.6	0.184
HR 5178	Kui 65	120033	13472-0943
	1983.0701	243.0	0.333
	1983.4332	242.4	0.335
	1984.0531	243.5	0.333
	1984.3779	243.2	0.323
	1984.3807	241.4	0.330
ADS 9031	STF 1785	120476	13492+2659
	1983.0510	164.8	3.288
-13 3786	RST 3852	121136	13539-1439
	1983.4307	137.1	0.154
	1984.3862	132.8	0.137
GL 9465	Ald 112	------	14019+1530
	1983.0510	182.3	1.579
ADS 9094	Bu 1270	122769	14037+0829
	1984.3754	58.5	0.153
	1984.3781	58.0	0.158
	1984.3835	59.2	0.153
HR 5298	CHARA 40	123630	14090-1020
	1983.4307	31.6	0.287
ADS 9158	STT 277 AB	124346	14124+2843
	1983.0510	40.0	0.309
	1984.0559	41.2	0.301
	1984.3728	41.4	0.302
	1984.3754	41.4	0.302
	1985.4813	42.4	0.302
ADS 9174	STF 1816	124587	14139+2906
	1983.0510	88.6	0.751
	1984.3728	88.8	0.741
	1984.3781	88.9	0.737
HR 5323	CHARA 41 AC	124570	14141+1258
	1984.3754	120.3	0.190
ADS 9182	STF 1819	124757	14153+0308
	1984.3754	234.0	0.857
+27 2367	DAN	125709	14205+2634
	1984.3754	170.6	0.054
ADS 9247	Bu 1111 BC	126128	14234+0827
	1984.3754	45.9	0.273
ADS 9264	A 2069	126695	14268+1625
	1984.3754	262.4	0.179
	1984.3781	265.5	0.174
	1985.4841	258.5	0.200
HR 5435	γ Boo	127762	14321+3819
	1984.3835	177.5	0.177
ADS 9301	A 570	127726	14323+2641
	1983.0701	340.0	0.161
	1983.4307	334.2	0.155
	1984.0559	324.8	0.151
	1984.3728	320.5	0.155
	1984.3754	318.6	0.151
	1984.3835	318.6	0.151
	1985.4813	298.7	0.152
ADS 9323	CHARA 42 Aa	128563	14373+0217
	1984.3865	161.0	0.210
ADS 9329	STF 1863	128941	14381+5135
	1983.0701	67.5	0.643
	1984.3754	68.4	0.636
	1984.3809	68.4	0.638
	1985.4813	68.1	0.651

TABLE IV. (continued)

HR 5472	McA 40	129132	14403+2158
	1983.0701	267°1	0″070
	1984.3835	244.4	0.048
−21 3946	RST 2917	129065	14411−2237
	1984.3755	187.4	0.364
	1984.3781	187.5	0.374
ADS 9343	STF 1865 AB	129246-7	14411+1344
	1984.0532	303.8	0.961
	1984.3781	303.5	0.961
	1984.3837	303.0	0.965
	1985.4895	302.8	0.969
ADS 9352	Hu 575 AB	------	14426+1930
	1983.0702	338.5	0.501
	1985.4895	323.3	0.427
ADS 9378	STT 285	130188	14455+4222
	1983.0701	331.3	0.276
	1984.3729	325.1	0.287
	1984.3782	326.3	0.285
	1985.4814	321.4	0.301
	1985.4896	320.8	0.307
HR 5504	Fin 309	129980	14462−2110
	1984.3755	274.8	0.186
	1984.3781	274.4	0.187
ADS 9389	STF 1884	130603	14485+2422
	1984.3782	56.3	2.036
ADS 9392	STF 1883	130604	14489+0557
	1983.0702	291.8	0.445
	1984.3729	289.7	0.475
	1985.4814	289.3	0.511
ADS 9395	Hu 141	130558	14492−1050
	1983.0702	109.9	0.289
	1983.4199	109.9	0.285
ADS 9396	Bu 106 AB	130559	14493−1409
	1984.3755	1.0	1.820
ADS 9400	A 1110 AB	130726	14497+0800
	1983.0702	246.8	0.615
	1984.3729	248.7	0.618
	1985.4814	248.4	0.637
ADS 9425	STT 288	131473	14534+1543
	1984.3837	171.1	1.316
	1984.3865	170.9	1.315
ADS 9453	Bu 239	132219	14587−2739
	1984.3755	350.3	0.557
	1984.3781	350.5	0.534
+47 2190	Cou 1760	------	14593+4649
	1984.3755	202.2	0.187
	1985.4841	204.4	0.195
ADS 9480	Bu 348 AB	132933	15018+0008
	1983.4200	109.2	0.502
	1984.3729	109.5	0.505
	1985.4814	109.0	0.511
ADS 9494	STF 1909	133640	15039+4739
	1983.4200	41.7	1.151
	1984.0532	42.7	1.193
	1984.3729	43.3	1.210
	1984.3782	43.2	1.216
	1985.4841	44.7	1.314
ADS 9515	RST 4534 AB	134213	15089−0610
	1983.4199	11.6	0.356
ADS 9530	A 1116	134827	15116+1008
	1983.0702	46.0	0.742
	1983.4200	47.3	0.738
	1984.3729	46.9	0.729
	1984.3781	46.5	0.740
HR 5654	Cou 189	134943	15121+1858
	1983.4281	143.2	0.442
	1984.0532	144.8	0.446
	1984.3755	143.5	0.443
	1984.3781	144.1	0.441
	1985.4895	143.2	0.453
ADS 9532	B 2351 Aa	134759	15123−1947
	1983.4308	6.0	0.154
	1984.0587	1.6	0.167
	1984.3755	358.1	0.150
−12 4227	CHARA 44	135681	15168−1302
	1983.4199	175°6	0″192
ADS 9578	STF 1932 AB	136176	15183+2649
	1983.4281	253.0	1.431
	1984.3865	253.4	1.457
ADS 9578	CHARA 45 Aa	136176	15183+2649
	1984.3837	66.3	0.333
+24 2847	Cou 103	------	15200+2338
	1983.4200	282.4	0.538
ADS 9617	STF 1937 AB	137107-8	15232+3018
	1983.0702	355.4	0.663
	1983.4281	359.1	0.669
	1984.3729	5.3	0.744
	1984.3782	5.0	0.743
	1985.4896	10.6	0.829
+40 2878	Cou 1441	------	15233+4022
	1984.3782	14.9	0.226
	1985.4841	16.7	0.248
ADS 9626	STF 1938 BC	137392	15245+3721
	1983.4200	15.2	2.096
ADS 9628	Bu 149	137588	15246+5413
	1983.4281	273.6	0.593
	1984.3729	273.6	0.599
+42 2601	Cou 1443	137896	15272+4133
	1983.4200	178.6	0.474
	1984.3782	178.1	0.487
	1985.4841	178.3	0.498
HR 5747	β CrB	137909	15278+2906
	1983.0511	163.7	0.200
	1983.0702	162.3	0.205
	1983.4200	160.6	0.221
	1983.7150	158.0	0.243
	1984.0587	156.2	0.263
	1984.3756	153.8	0.276
	1984.7007	153.1	0.285
	1985.4814	148.2	0.306
	1985.4841	148.4	0.306
ADS 9682	Hu 1163	138439	15307+3810
	1984.3782	28.4	0.113
	1985.4814	39.4	0.110
ADS 9688	A 1634 AB	138629	15318+4053
	1984.3756	198.6	0.055
HR 5778	Cou 610	138749	15329+3121
	1983.4281	203.4	0.671
	1984.3756	203.0	0.678
	1985.4814	202.8	0.696
	1985.4896	202.7	0.694
+27 2513	Cou 798	------	15347+2655
	1983.4200	57.2	0.154
	1985.4841	64.1	0.139
ADS 9716	STT 298 AB	139341	15361+3948
	1983.4281	230.5	0.470
	1984.3756	237.0	0.420
	1984.3782	237.1	0.419
ADS 9731	STF 1964 CD	139691	15382+3614
	1983.4281	18.9	1.532
−19 4165	CHARA 48	139364	15384−1955
	1983.4308	165.9	0.271
+26 2712	Cou 612	139749	15390+2545
	1983.4200	275.3	0.170
	1984.3756	267.7	0.179
	1985.4843	261.6	0.186
ADS 9735	Bu 122	139628	15399−1947
	1983.4308	223.5	1.785
ADS 9742	A 2076	139939	15405+1841
	1983.4200	180.1	0.632
	1984.3757	180.4	0.635
	1985.4843	180.5	0.647
ADS 9744	Hu 580 AB	140159	15416+1941
	1983.0702	74.7	0.156
	1983.4281	77.8	0.138
	1984.3757	84.1	0.087

TABLE IV. (continued)

+42 2629	Cou 1445	140432	15420+4204
	1983.4200	222°.3	0".139
	1985.4841	223.4	0.113
ADS 9757	STF 1967	140436	15428+2618
	1983.4200	120.7	0.425
	1984.3756	120.4	0.448
	1985.4843	119.4	0.486
ADS 9758	Bu 619	140438	15431+1340
	1983.4282	3.6	0.655
	1983.4308	3.3	0.658
	1984.3757	3.1	0.660
	1985.4843	3.5	0.675
+22 2878	Cou 106	140629	15440+2220
	1983.4200	272.8	0.392
	1985.4843	272.3	0.400
ADS 9775	Bu 620 AB	140722	15462-2804
	1983.4282	170.6	0.534
	1984.3783	170.8	0.528
	1985.4978	170.8	0.543
ADS 9775	CHARA 50 Aa	140722	15462-2804
	1983.4282	71.7	0.216
	1984.3783	108.3	0.199
Gl 9529AB	Cou 66	------	15465+1956
	1985.4896	144.2	0.876
ADS 9783	A 2077	------	15469+1904
	1985.4843	233.1	0.544
ADS 9794	A 1127	141730	15474+5929
	1983.4200	286.7	0.316
	1984.3729	287.9	0.312
	1985.4841	288.0	0.324
ADS 9806	Hu 912	142089	15492+6032
	1983.4200	280.9	0.169
	1984.3729	286.3	0.168
	1984.3756	286.8	0.155
	1985.4841	295.5	0.134
ADS 9812	Hu 153	141898	15519-1232
	1983.4200	71.9	0.410
	1985.4923	74.1	0.408
ADS 9834	Hu 1274	142378	15550-1923
	1983.4254	120.6	0.556
ADS 9836	I 977	142456	15557-2645
	1983.4254	151.4	0.248
	1984.3783	152.3	0.178
HR 5953	δ Sco	143275	16003-2237
	1983.4254	172.6	0.173
	1984.3783	174.7	0.171
ADS 9909	STF 1998 AB	144069-0	16044-1122
	1983.4282	27.5	0.981
	1984.3783	29.4	0.954
ADS 9913	Bu 947 AB	144217	16054-1948
	1983.4282	132.9	0.379
	1984.3783	132.9	0.376
	1985.4868	134.9	0.368
ADS 9913	McA 42 CE	144218	16054-1948
	1983.4226	68.7	0.108
	1984.3783	85.2	0.087
ADS 9931	A 1798	144935	16079+1425
	1983.4200	25.9	0.156
	1983.7151	27.3	0.157
	1984.3730	25.4	0.155
	1985.4844	24.0	0.159
ADS 9935	Bu 355 AB	145246	16081+4524
	1983.4200	280.5	0.281
	1984.3730	281.3	0.275
	1985.4844	281.0	0.270
ADS 9932	Bu 949	144892	16085-1006
	1983.4282	194.3	0.405
	1984.3729	194.2	0.417
	1985.4869	194.6	0.428
-3012880	I 557	144926	16094-3103
	1983.4254	226.6	0.199
HR 6032	Fin 354	145589	16115+0943
	1983.4200	83°.2	0".124
	1983.7151	85.8	0.126
	1984.3730	84.0	0.130
	1984.3757	84.3	0.124
	1985.4843	84.3	0.127
ADS 9951	Bu 120	145501-2	16120-1927
	1983.4282	2.0	1.219
ADS 9969	CHARA 52 Aa	145958	16133+1333
	1983.4281	123.7	0.209
ADS 9971	RST 3936 AB	145996	16143-1024
	1983.4200	267.9	0.302
	1984.3729	267.6	0.302
-3012986	I 1586	146177	16161-3037
	1983.4254	257.4	0.321
ADS 10006	STT 309	147275-6	16192+4140
	1983.4200	284.0	0.318
	1984.3730	286.0	0.310
	1985.4814	287.0	0.322
ADS 10005	B 1808 AB	147104	16205-2008
	1984.3783	173.9	0.117
HR 6084	σ Sco Aa	147165	16212-2536
	1983.4254	92.9	0.377
	1984.3783	92.3	0.384
HR 6103	CHARA 53 Aa	147677	16221+3053
	1984.3783	74.7	0.153
-16 4280	CHARA 54	147473	16229-1701
	1984.3783	91.6	0.081
	1985.4978	89.9	0.105
ADS 10052	STF 2054	148374	16238+6141
	1983.4309	352.6	1.009
	1984.3784	352.5	1.008
	1985.4844	352.4	1.019
ADS 10068	Bu 814	148552	16272+3952
	1983.4202	352.8	0.312
	1985.4814	353.5	0.310
-15 4324	RST 3950	148394	16286-1613
	1983.4254	70.8	0.261
	1984.3783	69.2	0.267
ADS 10075	STF 2052 AB	148653	16289+1825
	1983.4309	131.6	1.535
	1984.3730	130.9	1.561
	1985.4844	130.1	1.617
ADS 10087	STF 2055 AB	148857	16310+0159
	1983.4308	15.3	1.216
	1984.3730	16.4	1.227
ADS 10092	STF 3105	148931	16318-0702
	1983.4308	202.9	0.331
	1984.3729	202.3	0.342
	1985.4869	201.1	0.347
HR 6168	σ Her	149630	16341+4227
	1984.7007	204.0	0.083
	1985.4844	198.9	0.102
ADS 10129	STF 2078 AB	150117-8	16363+5255
	1983.4309	105.5	3.213
+74 0680	MLR 198	151746	16420+7353
	1983.4309	186.7	0.209
	1983.7151	185.4	0.204
	1984.3730	183.6	0.194
	1985.4844	177.9	0.183
ADS 10189	Hu 664	151267	16437+5132
	1983.4202	301.8	0.464
	1984.3730	301.7	0.463
	1984.3784	301.7	0.467
	1985.4814	302.6	0.479
ADS 10184	STF 2094 AB	151070	16442+2331
	1983.4309	74.8	1.230
	1984.3784	74.9	1.229
+72 0751	MLR 182	152027	16446+7145
	1983.7151	41.9	0.164
	1984.3784	29.0	0.153
	1985.4844	20.0	0.151

TABLE IV. (continued)

+29 2876	Cou 490	151236	16450+2928
	1983.4200	26°6	0″191
	1984.3784	25.0	0.197
	1985.4845	21.2	0.197
ADS 10229	STF 2106	152113	16511+0925
	1983.4309	180.3	0.545
	1984.3784	180.5	0.550
-2412876	B 2397	151902	16514-2450
	1984.3812	336.3	0.097
ADS 10230	STT 315	152127	16515+0113
	1983.4200	352.9	0.186
	1984.3784	347.8	0.207
	1984.3840	346.8	0.201
	1984.7009	345.6	0.213
	1985.4845	342.4	0.235
ADS 10252	B 323	152535	16550-2431
	1983.4254	92.5	0.475
ADS 10257	Bu 241	152655	16555-2134
	1983.4282	8.8	0.368
	1984.3785	9.0	0.362
	1984.3812	9.6	0.369
ADS 10279	STF 2118	153697	16563+6502
	1983.4309	70.2	1.111
	1984.3730	70.3	1.099
	1984.3784	70.5	1.111
ADS 10265	Bu 1117	152849	16568-2309
	1983.4282	297.7	0.953
	1984.3785	297.6	0.955
ADS 10287	Hu 162	153305	16593-1655
	1984.3785	215.9	0.624
ADS 10312	STF 2114	153914	17019+0827
	1983.4308	186.9	1.229
	1984.3785	187.5	1.230
ADS 10345	STF 2130 AB	154905-6	17054+5427
	1982.5027	42.8	2.034
	1983.4309	42.2	2.044
+38 2885	Cou 1291	155039	17075+3810
	1984.3784	217.8	0.108
	1985.4844	228.5	0.109
ADS 10360	Hu 1176 AB	155103	17081+3555
	1982.5027	347.1	0.069
	1983.0702	315.6	0.067
	1984.3784	144.5	0.074
	1984.7008	134.7	0.095
	1985.4816	120.6	0.129
ADS 10355	A 1145	154895	17082-0105
	1983.4200	17.8	0.412
	1984.3785	16.4	0.424
	1984.3840	15.6	0.423
	1985.4845	14.1	0.440
-19 4547	McA 46	155095	17103-1926
	1984.3785	115.0	0 123
	1984.3812	115.0	0.122
ADS 10374	Bu 1118 AB	155125	17103-1544
	1984.3785	260.2	0.383
	1984.3812	260.1	0.385
	1985.4869	258.1	0.403
ADS 10385	Hu 169	155317	17115-1629
	1983.4254	43.5	0.165
	1984.3785	35.4	0.153
	1984.3812	34.7	0.147
+45 2505	Kui 79 AB	155876	17121+4544
	1982.5027	254.9	1.008
	1984.3784	241.9	1.120
	1985.4844	234.0	1.127
ADS 10423	A 2592	156034	17157-0949
	1983.4202	227.7	0.357
	1984.3785	224.9	0.360
	1984.3811	224.9	0.361
	1985.4869	223.1	0.340
-3013996	Fu 1119	156184	17173-3010
	1983.4255	83.2	0.341
	1984.3812	86.0	0.321
ADS 10459	Bu 628	------	17184+3239
	1984.3732	284°8	0″462
ADS 10465	Bu 126 AB	156717	17198-1745
	1983.4310	262.9	2.296
HR 6469	McA 47	157482	17217+3958
	1982.5027	154.5	0.106
	1983.0702	161.6	0.108
	1983.4202	165.4	0.101
	1983.7151	171.0	0.102
	1984.3732	180.2	0.095
	1984.3760	181.5	0.083
	1984.3840	181.6	0.082
	1984.7009	188.6	0.072
	1985.4816	225.4	0.051
+23 3092	Cou 415	157392	17221+2310
	1983.4202	67.1	0.157
	1984.3759	54.5	0.146
	1984.3813	55.4	0.148
-09 4546	RST 3972	157498	17240-0921
	1983.4202	83.4	0.227
	1984.3757	93.0	0.219
	1984.3812	93.3	0.219
ADS 10531	Hu 1179	157853	17241+3834
	1984.3840	294.3	0.051
	1984.7009	294.8	0.056
ADS 10573	Bu 1201	158867	17263+6746
	1983.4202	343.4	0.195
	1984.3732	341.8	0.178
	1984.3760	342.4	0.181
ADS 10561	A 2244	158122	17283-2058
	1984.3785	88.2	0.232
	1985.4843	85.7	0.245
ADS 10585	A 351	------	17294+2924
	1982.5027	242.5	0.535
	1983.4202	243.9	0.584
ADS 10598	STF 2173	158614	17303-0103
	1983.4309	160.6	0.770
	1984.3757	159.0	0.837
	1984.3812	159.0	0.837
+19 3336	Cou 499	158956	17313+1901
	1984.3813	60.6	0.150
ADS 10624	Hu 1181	159304	17326+3445
	1983.4202	8.6	0.116
	1983.7152	9.6	0.113
	1984.3759	18.5	0.083
	1984.3840	18.9	0.080
HR 6560	Mlr 571	159870	17335+5734
	1982.5027	359.3	0.149
	1983.0702	352.6	0.147
	1983.4202	356.1	0.142
	1983.7151	355.6	0.144
	1984.3732	355.3	0.143
	1984.3760	353.1	0.140
	1984.3840	353.3	0.141
+68 0946	CHARA 62 Aa	------	17365+6823
	1984.3760	1.3	0.292
+45 2566	Cou 1595	160214	17365+4543
	1982.5027	250.4	0.414
	1983.4309	252.9	0.408
ADS 10659	A 1156	159857	17366+0722
	1984.3759	3.8	0.084
	1984.3813	3.8	0.079
	1985.4869	2.1	0.084
ADS 10657	Hu 751	159663	17368-2058
	1985.4843	240.7	0.090
+27 2853	Kui 83 AB	------	17370+2753
	1982.5028	10.3	0.241
	1983.4202	349.7	0.229
	1983.4309	349.7	0.224
	1984.3813	329.9	0.220

TABLE IV. (continued)

ADS 10696	Bu 631		160438	17399-0039
		1983.4202	140°3	0″085
		1983.7152	140.3	0.091
		1984.3757	135.4	0.093
		1984.3812	135.2	0.092
		1984.7007	131.8	0.093
		1985.4816	130.1	0.106
+21 3188	Cou 114		160935	17418+2130
		1982.5028	30.8	0.288
		1983.4312	32.2	0.286
		1984.3759	32.5	0.284
		1984.3813	32.4	0.283
		1985.4816	32.7	0.290
ADS 10743	Hu 1285		161258	17436+2237
		1983.4203	224.2	0.546
		1984.3759	223.7	0.551
		1984.3813	223.7	0.550
		1985.4869	223.1	0.553
ADS 10786	AC 7 BC		161797	17465+2745
		1983.4312	49.6	1.475
		1985.4978	55.8	1.610
HR 6641	CHARA 64		162132	17471+4737
		1985.4924	110.4	0.144
ADS 10795	STF 2215		161833	17472+1742
		1983.4255	266.4	0.558
		1985.4869	265.6	0.563
+37 2949	Cou 1145		162338	17490+3704
		1982.5027	7.4	0.105
		1983.0703	0.2	0.108
		1983.4227	357.4	0.114
		1983.7152	352.7	0.117
		1984.3759	345.5	0.117
		1984.3840	346.6	0.117
		1985.4816	335.7	0.128
ADS 10828	STT 337		162405	17505+0715
		1983.4203	178.6	0.380
		1984.3759	178.4	0.385
		1984.3813	177.9	0.382
		1985.4869	177.4	0.401
+36 2956	Cou 1146		162667	17505+3651
		1983.4227	151.9	0.249
		1983.7152	152.4	0.245
		1984.3759	152.2	0.247
ADS 10846	A 1164		162670	17519+0724
		1983.4203	42.8	0.361
		1984.3757	43.1	0.371
		1984.3812	43.5	0.363
		1985.4869	43.2	0.363
ADS 10850	STT 338 AB		162734	17520+1520
		1982.5028	352.6	0.812
		1983.4255	351.4	0.798
		1984.3759	351.4	0.798
		1984.3813	351.3	0.795
ADS 10866	AC 8		163032	17528+2941
		1983.4227	274.6	0.202
		1984.3785	273.3	0.202
ADS 11006	STT 349		167101	17530+8354
		1983.4227	45.2	0.355
		1983.7153	46.2	0.369
		1984.3732	47.0	0.358
ADS 10871	A 235		163077	17533+2500
		1983.4312	77.0	0.373
		1984.3787	78.6	0.384
HR 6676	Fin 381		163151	17543+1108
		1983.4255	326.6	0.117
		1983.7152	325.7	0.117
		1984.3787	303.7	0.106
		1984.3842	305.1	0.106
+41 2928	Cou 1601 Aa		------	17556+4108
		1982.5027	65.1	0.515
		1983.4312	66.6	0.535
+25 3381	Cou 503		163529	17556+2508
		1983.4203	88.3	0.368
		1984.3787	89.1	0.361
ADS 10899	A 2189		163471	17563+0259
		1984.3787	339°0	0″112
		1984.3842	342.2	0.121
ADS 10905	McA 49 Aa		163640	17564+1820
		1983.7097	69.1	0.069
ADS 10905	STF 2245 Aa,B		163640	17564+1820
		1982.5028	292.9	2.534
		1983.7097	291.6	2.609
ADS 10912	STF 2244		163624	17571+0004
		1983.4312	88.3	0.278
		1984.3787	90.8	0.294
		1984.3842	92.0	0.295
-19 4777	CHARA 66		163680	17582-1916
		1983.4312	110.0	0.392
+04 3562	Kui 84		------	17584+0427
		1985.4872	100.7	0.142
+24 3298	Cou 115		------	18000+2449
		1983.4203	111.0	0.271
		1983.7098	114.6	0.267
		1984.3787	112.9	0.272
ADS 11005	STF 2262 AB		164764-5	18030-0811
		1983.4312	276.6	1.860
+40 3270	Cou 1785		165311	18035+4032
		1983.4227	57.7	0.156
		1984.3760	54.7	0.142
+42 2995	Cou 1786		165503	18043+4205
		1984.3840	129.6	0.084
		1985.4978	144.5	0.085
ADS 11060	STT 341 AB		165590	18059+2126
		1982.5083	89.7	0.364
		1982.7650	90.1	0.384
		1983.4203	89.1	0.406
		1983.7098	90.6	0.427
		1984.3787	90.7	0.443
		1985.8423	90.5	0.478
ADS 11071	Hu 1186		------	18063+3824
		1983.4227	102.1	0.441
		1983.7098	101.3	0.451
ADS 11080	STT 524		165886	18075+1939
		1983.4203	227.1	0.282
		1983.7097	227.6	0.288
		1984.3787	225.9	0.291
ADS 11098	Hu 314		166157	18086+1839
		1983.4203	96.5	0.287
		1984.3787	96.9	0.288
ADS 11111	STF 2281 AB		166233	18095+0401
		1982.5083	330.7	0.345
		1982.7650	326.6	0.342
		1983.4312	325.0	0.343
		1983.7097	324.2	0.346
		1984.3787	322.2	0.349
ADS 11128	Hu 674		166820	18097+5024
		1983.4203	228.7	0.692
		1983.7152	229.8	0.699
		1984.3732	229.0	0.699
		1985.4869	228.0	0.712
-2314005	RST 5104		166107	18101-2346
		1983.4227	165.0	0.218
ADS 11149	B 2545 AB		166988	18117+3327
		1982.7651	57.3	0.099
		1983.0703	54.1	0.102
		1983.4203	58.4	0.094
		1983.7097	60.3	0.107
		1984.3785	60.4	0.102
		1984.3840	60.4	0.102
		1985.4816	62.2	0.104
-20 5068	McA 51		167570	18167-2032
		1982.7650	135.2	0.256
		1983.4227	133.2	0.249
ADS 11228	Bu 246		167815	18177-1940
		1983.4227	112.3	0.475
HR 6851	CHARA 68		168199	18180+1347
		1985.8423	41.1	0.055

TABLE IV. (continued)

+20 3741	Cou 202	168743	18205+2055
	1983.4203	267°5	0"245
	1985.4845	272.3	0.249
HR 6927	X Dra	170153	18208+7245
	1983.0703	224.8	0.149
	1983.7152	211.9	0.119
	1984.7009	233.5	0.118
	1985.4846	238.4	0.115
+23 3312	Cou 418	169030	18217+2356
	1983.4203	70.0	0.193
	1985.4845	69.8	0.191
-16 4836	CHARA 69	168701	18218-1619
	1985.4899	11.0	0.089
ADS 11324	AC 11	169493	18249-0135
	1983.4312	356.3	0.814
ADS 11334	STF 2315 AB	169718	18250+2723
	1982.7650	129.3	0.631
	1983.4312	128.3	0.627
	1984.3787	128.3	0.626
	1984.7117	128.5	0.626
	1985.4871	127.6	0.639
ADS 11344	Hu 66 AB	170109	18253+4845
	1983.4203	253.0	0.318
	1983.7153	253.0	0.324
	1984.3787	252.5	0.319
	1984.7035	251.7	0.324
	1985.4846	251.4	0.322
ADS 11344	ST 351 AC	170109	18253+4845
	1983.4203	18.0	0.670
	1983.7153	18.8	0.673
	1984.3787	18.4	0.671
	1984.7035	19.0	0.671
	1985.4846	18.5	0.683
ADS 11339	Bu 1203	169725	18261+0046
	1983.4312	142.9	0.393
HR 6928	CHARA 71	170200	18280+0612
	1985.8424	130.8	0.077
ADS 11399	CHARA 72 Aa	170580	18301+0404
	1985.8424	176.0	0.142
ADS 11454	Hu 322 AB	171365	18338+1744
	1983.4203	87.4	0.216
	1983.7153	88.5	0.219
	1984.3760	90.1	0.230
	1984.3842	91.8	0.225
	1985.4845	88.0	0.229
ADS 11468	A 1377 AB	171779	18340+5221
	1982.7650	96.0	0.260
	1983.4312	98.0	0.260
	1984.3760	99.1	0.261
	1984.7035	99.4	0.261
	1985.4846	99.7	0.264
HR 6977	CHARA 74	171623	18352+1812
	1985.8424	31.1	0.156
HR 6984	CHARA 75	171780	18352+3427
	1985.8424	76.0	0.253
ADS 11479	STT 359	171745	18355+2336
	1984.3787	9.9	0.619
	1985.4845	9.6	0.633
ADS 11483	STT 358 AB	171746	18359+1659
	1983.4312	161.4	1.666
	1984.3787	161.1	1.659
+21 3492	Cou 206	342628	18363+2143
	1983.4203	123.9	0.143
	1985.4845	123.7	0.120
ADS 11584	STT 363	173831	18374+7741
	1982.5029	156.1	0.131
	1933.4204	153.3	0.124
	1983.7153	157.7	0.118
	1984.3787	159.3	0.102
	1984.7009	162.0	0.083
	1985.4846	171.6	0.065
ADS 11524	Hu 198	172171	18383+0850
	1983.4312	136.1	0.438
	1985.4871	134.9	0.450
ADS 11520	A 88 AB	172088	18384-0312
	1984.3842	12°6	0"108
	1985.4899	350.1	0.139
ADS 11530	Ho 87 AB	172246	18386+1632
	1983.4203	33.3	0.215
	1984.3760	36.4	0.226
	1985.4845	41.0	0.242
ADS 11558	STF 2368 AB	172712	18389+5221
	1983.4312	321.1	1.857
HR 7017	Cou 1607	172671	18395+4056
	1982.7650	114.0	0.179
	1983.0703	114.3	0.179
	1983.4312	114.2	0.177
	1984.3760	114.2	0.175
	1984.3842	114.2	0.176
	1984.7035	114.6	0.176
	1985.4846	114.0	0.178
ADS 11566	Ho 437 AB	172729	18406+3138
	1983.4203	130.1	0.413
	1984.3787	130.4	0.411
	1984.7117	130.8	0.411
	1985.4846	130.7	0.415
ADS 11574	A 2988	172743	18410+2450
	1984.7009	172.5	0.134
ADS 11579	STF 2367 AB	172865	18413+3018
	1983.0703	113.9	0.059
	1983.7153	101.0	0.097
	1984.3787	99.1	0.091
	1984.3842	100.1	0.093
	1984.7009	98.8	0.101
	1985.4845	95.7	0.119
ADS 11593	B 2546 Aa	173087	18421+3445
	1982.7650	295.5	0.153
	1983.4204	296.8	0.147
	1984.3787	299.2	0.144
	1984.7117	300.2	0.144
	1985.4846	301.3	0.146
+18 3786	Cou 816	229303	18433+1847
	1983.4204	302.1	0.262
	1983.7153	301.3	0.257
	1985.4845	300.7	0.260
ADS 11614	A 859	173160	18439-0013
	1983.4203	13.6	0.255
	1985.4899	14.7	0.255
ADS 11635	STF 2382 AB	173582-3	18443+3940
	1985.4729	354.6	2.501
	1985.4872	354.2	2.496
ADS 11635	STF 2383 CD	173607-8	18444+3937
	1985.4729	89.0	2.353
	1985.4872	89.3	2.358
HR 7035	CHARA 78	173117	18448-2501
	1983.4227	3.1	0.084
ADS 11640	Fin 332 Aab	173495	18455+0530
	1983.4203	131.4	0.153
	1985.4816	129.7	0.137
	1985.8424	128.2	0.138
ADS 11640	Fin 332 Bab	173495	18455+0530
	1985.4816	140.3	0.138
	1985.8424	139.4	0.138
ADS 11640	STF 2375 AB	173495	18455+0530
	1982.5029	119.4	2.440
	1982.7650	118.1	2.512
ADS 11640	Fin 332 Aa,Bb	173495	18455+0530
	1982.5029	120.3	2.580
	1982.7650	119.2	2.651
ADS 11640	Fin 332 Ab,Ba	173495	18455+0530
	1982.5029	118.3	2.319
	1982.7650	117.0	2.382
-08 4701	RST 4597	173611	18466-0807
	1983.4203	321.1	0.436
	1984.3813	321.4	0.438
	1984.7036	321.6	0.440
	1985.4872	320.5	0.442

TABLE IV. (continued)

ADS 11698	Bu 971 AB		174343-4	18475+4926
		1982.7650	37°1	0″286
		1984.3787	36.0	0.291
		1984.7009	37.6	0.292
		1985.4846	37.9	0.304
-18 5070	RST 3198		173805-6	18480-1814
		1984.3815	153.6	0.396
HR 7072	Kui 88		173928	18487-1836
		1983.4229	165.3	0.370
		1984.3815	165.5	0.403
		1984.7036	165.9	0.409
		1985.4900	165.4	0.411
HR 7109	CHARA 80		174853	18520+1358
		1985.8424	97.5	0.101
+24 3555	Cou 510		174932	18521+2431
		1983.4204	154.4	0.189
		1983.7153	154.1	0.188
		1985.4872	156.8	0.190
ADS 11803	A 1891		175060	18541-1352
		1983.4203	258.4	0.353
		1984.3813	258.4	0.355
ADS 11842	A 2192		175543	18558+0327
		1983.4229	93.5	0.261
		1984.3813	89.9	0.262
		1934.7035	89.7	0.262
		1985.4872	87.9	0.265
ADS 11897	STF 2438		176560	18575+5814
		1983.4204	3.4	0.795
		1984.3787	3.3	0.798
		1984.7117	3.4	0.801
		1985.4871	2.8	0.814
ADS 11884	CHARA 82 Aa		176155	18582+1722
		1984.3843	174.7	0.154
HR 7166	Kui 89		176162	18594-1250
		1982.7650	264.5	0.174
		1983.4229	265.9	0.159
		1984.3813	271.0	0.154
		1984.7036	273.4	0.151
		1985.4872	279.4	0.144
+39 3606	Cou 1933		176869	19006+3951
		1983.4204	203.4	0.477
		1983.7125	202.1	0.473
		1984.3788	201.1	0.477
		1984.7117	201.4	0.477
		1985.4899	201.5	0.488
ADS 11950	HDO 150 AB		176687	19026-2953
		1983.4313	86.8	0.349
		1984.3815	77.1	0.384
ADS 11989	H 126		177166	19043-2132
		1983.4313	204.6	1.157
		1984.3815	204.5	1.155
ADS 12032	Ho 95		177936	19056+2717
		1983.4204	179.0	0.173
		1983.7125	180.4	0.177
		1984.3788	178.5	0.173
		1984.3842	180.0	0.173
		1984.7009	178.6	0.172
		1985.4871	177.0	0.172
		1985.8424	176.9	0.176
ADS 12055	MLR 217 Aa		178634	19058+5918
		1984.3787	78.9	0.171
HR 7262	ι Lyr		178475	19073+3606
		1984.3788	52.9	0.074
		1984.3842	53.5	0.078
		1984.7009	53.4	0.079
		1985.4899	50.5	0.081
ADS 12061	Kui 90 Ca		178449	19074+3230
		1985.4899	176.5	0.315
ADS 12079	Ho 98 AB		178617	19081+2705
		1983.4175	87.4	0.266
		1983.7125	89.2	0.266
		1984.3788	88.4	0.261
		1984.7009	88.4	0.262
		1985.4899	86.9	0.263
-05 4884	RST 4618		178286	19082-0520
		1985.4872	137°9	0″081
+12 3818	McA 54		178452-3	19083+1215
		1982.5056	188.2	0.177
		1983.4176	181.2	0.182
		1983.7125	185.7	0.170
		1984.3813	185.8	0.168
		1984.3843	186.6	0.164
		1984.7035	186.4	0.165
		1985.4872	185.1	0.171
		1985.8424	184.7	0.168
ADS 12101	CHARA 84 Aa		178911	19091+3436
		1985.8424	155.9	0.084
ADS 12126	A 95		179002	19110-0725
		1982.7651	70.9	0.290
		1983.4230	69.9	0.289
		1984.3733	69.3	0.284
		1984.7037	68.9	0.291
		1985.4872	67.4	0.295
ADS 12147	Bu 1204 AB		179343	19120+0237
		1983.4230	185.3	0.247
		1983.7125	186.4	0.246
		1984.3815	186.3	0.245
		1984.7037	185.9	0.242
		1985.4873	185.6	0.245
+20 4076	Cou 320		179528	19123+2113
		1983.4176	114.5	0.195
		1983.7125	115.2	0.198
		1984.7037	113.8	0.194
		1985.4873	112.2	0.203
ADS 12160	Bu 139 AB		179588	19126+1651
		1983.4176	136.1	0.655
		1984.7037	136.0	0.655
		1985.4873	135.7	0.660
ADS 12214	B 430		179950	19155-2515
		1982.5056	103.2	0.176
		1983.4230	104.2	0.191
		1984.3732	104.0	0.199
		1984.7036	107.1	0.199
ADS 12261	A 1392		181044	19158+5458
		1983.7125	74.0	0.203
		1984.7037	73.7	0.185
		1985.4900	74.5	0.166
ADS 12239	STT 371 AB		180553	19159+2727
		1983.4313	158.1	0.846
		1984.7091	158.5	0.845
		1985.4873	158.1	0.863
ADS 12248	CHARA 85 Aa		180555	19164+1433
		1985.8533	40.0	0.055
ADS 12329	HWE 47		181527	19206+0256
		1983.4230	309.3	0.507
		1984.3733	309.1	0.501
		1985.4873	309.0	0.516
ADS 12366	Bu 1129		182353	19216+5223
		1982.5083	0.5	0.150
		1983.4175	1.3	0.140
		1983.7125	0.9	0.142
		1984.7037	0.2	0.145
		1985.4847	358.5	0.151
ADS 12501	A 160		183458	19288+2304
		1984.7009	72.9	0.301
		1985.4873	73.1	0.304
ADS 12552	A 712		184195	19303+5639
		1982.7568	95.3	0.128
		1983.4175	95.9	0.135
		1983.7126	94.2	0.139
		1984.7037	97.1	0.147
		1985.4900	95.9	0.151

TABLE IV. (continued)

ADS 12540	McA 55 Aa	183912	19307+2758
	1982.7542	172°8	0″407
	1982.7651	173.3	0.407
	1983.4175	171.9	0.395
	1983.7098	171.4	0.398
	1984.3733	169.7	0.394
	1985.4729	169.5	0.359
	1985.4816	166.7	0.400
ADS 12567	A 713	184242	19313+4729
	1983.4175	270.3	0.357
	1983.7126	271.0	0.365
	1985.4847	271.8	0.360
+58 1929	McA 56	184467	19311+5835
	1983.4175	46.9	0.112
	1984.7039	236.7	0.109
	1985.4900	141.4	0.065
ADS 12600	Ho 108	184470	19332+3329
	1983.4175	30.4	0.240
	1983.7098	29.9	0.230
	1984.7010	30.2	0.226
	1985.4846	28.2	0.230
	1985.8424	28.0	0.230
HR 7436	CHARA 87	184603	19336+3846
	1985.8424	175.7	0.138
ADS 12623	STT 375	184591	19347+1808
	1983.4176	176.0	0.594
	1983.7100	176.3	0.586
	1984.7037	177.1	0.593
	1985.4873	177.1	0.600
	1985.8369	177.0	0.595
HR 7441	9 Cyg	184759	19348+2928
	1985.8369	257.4	0.049
ADS 12631	A 162	184739	19351+2328
	1983.4176	254.8	0.237
	1983.7100	254.2	0.245
	1984.7010	256.5	0.241
	1985.4873	256.2	0.245
	1985.8369	256.6	0.233
+23 3711	Cou 1033	185058	19365+2400
	1983.4231	189.7	0.226
	1983.7100	187.7	0.220
	1984.7010	189.7	0.220
	1985.4873	189.3	0.230
	1985.8369	186.1	0.224
+63 1544	MLR 56 AD	185977	19376+6344
	1983.4231	91.9	0.122
	1985.4900	100.1	0.102
ADS 12743	I 656	185447	19400-2203
	1983.4258	11.9	0.116
+26 3631	Cou 822	185819	19400+2712
	1983.4258	143.6	0.236
	1984.7010	144.7	0.231
	1985.4900	145.1	0.236
HR 7486	Kui 93	185936	19412+1349
	1983.4231	307.4	0.168
	1983.7126	307.9	0.172
	1984.7010	308.2	0.175
	1985.4900	308.1	0.179
+85 0337	MLR 229	191079	19418+8552
	1985.4900	5.4	0.115
ADS 12798	STT 382	186179	19419+2723
	1982.5084	328.5	0.308
	1982.7651	329.5	0.313
	1983.4231	328.9	0.304
	1983.7126	329.1	0.307
	1984.7010	328.7	0.307
	1985.4900	327.8	0.310
HR 7499	Kui 94	186307	19419+4015
	1983.4258	143.4	0.162
	1983.7126	142.2	0.162
	1984.7039	135.9	0.137
	1985.4900	130.5	0.124
ADS 12808	STT 380 AB	186203	19426+1149
	1982.7651	77°1	0″443
	1983.4230	77.4	0.438
	1985.4901	77.4	0.444
ADS 12850	Bu 658	186518	19441+2708
	1983.4258	283.6	0.353
	1984.7010	284.4	0.354
	1985.4847	283.8	0.358
ADS 12864	AGC 10 AB	186587	19450+1046
	1983.4230	138.8	0.238
	1983.7126	139.4	0.239
ADS 12889	STF 2576 AB	186858	19456+3336
	1983.4313	354.5	2.115
	1983.7126	354.7	2.123
ADS 12906	A 1404 AB	186996	19459+3953
	1983.4231	296.9	0.165
	1983.7126	299.5	0.168
	1984.7039	298.1	0.166
	1985.4900	297.8	0.170
	1985.8370	295.5	0.148
-01 3824	RST 5143	186778	19466-0123
	1983.4230	130.9	0.228
	1983.7126	131.9	0.228
	1985.8534	133.9	0.233
ADS 12911	A 108	186847	19471-0810
	1983.4230	82.6	0.251
	1983.7126	87.3	0.271
	1985.8425	88.5	0.269
HR 7536	δ Sge	187076	19474+1832
	1983.4340	123.3	0.060
	1985.4846	81.3	0.058
ADS 12962	STF 2583 AB	187259	19487+1148
	1983.4313	107.4	1.422
	1985.4901	107.3	1.445
+18 4252	McA 58	187321-2	19487+1852
	1983.4313	97.7	0.405
	1984.7010	98.7	0.405
	1985.4900	97.8	0.414
	1985.8369	98.1	0.408
ADS 12973	AGC 11 AB	187362	19489+1908
	1982.5056	193.9	0.109
	1982.7651	191.4	0.119
	1983.4231	187.7	0.131
	1983.4258	187.9	0.132
	1983.4340	187.8	0.132
	1983.7155	186.8	0.139
	1984.7010	181.6	0.162
	1985.8369	176.9	0.186
ADS 12986	A 718 BC	187613	19490+4423
	1985.4900	37.3	0.214
HR 7554	CHARA 89	187567	19503+0754
	1985.8534	70.8	0.078
+23 3798	Cou 1034	187689	19504+2409
	1983.4231	207.7	0.248
	1983.7155	208.6	0.248
	1984.7039	209.1	0.252
	1985.4900	209.4	0.253
ADS 13048	B 454	187858	19531-2528
	1983.4258	340.4	0.279
HR 7571	CHARA 90	187949	19531-1436
	1985.8425	190.0	0.301
ADS 13135	Hu 687	188871	19549+5049
	1983.4231	341.7	0.127
	1983.7155	344.0	0.123
	1984.7039	347.2	0.121
	1985.4900	349.0	0.126
	1985.8372	355.7	0.129
ADS 13104	STF 2597	188405	19553-0644
	1982.7651	303.1	0.135
	1983.4230	303.4	0.137
	1984.7010	298.5	0.156
ADS 13191	Hu 689	189451	19577+5119
	1983.7155	330.4	0.085
	1984.7012	329.1	0.065

TABLE IV. (continued)

ADS 13176	AC 16 AB	189214	19579+2715
	1983.7155	235°9	0"418
	1984.7039	235.9	0.415
ADS 13186	STT 392 AB	189377	19579+4215
	1983.4176	222.7	0.107
	1983.7155	220.3	0.095
	1984.7012	217.1	0.096
	1985.8425	213.9	0.097
ADS 13198	STF 2609	189432	19586+3807
	1983.4286	24.0	1.909
HR 7637	Ho 276	189340	19599-0957
	1983.4258	228.7	0.141
ADS 13277	STT 395	190004	20018+2456
	1982.7542	119.2	0.855
	1983.4258	119.0	0.845
	1984.7039	119.7	0.842
	1984.7117	119.9	0.843
ADS 13312	STF 2624 AB	190429	20035+3602
	1982.7596	173.8	1.901
	1983.4286	173.7	1.875
HR 7677	CHARA 92	190590	20050+2313
	1985.8425	48.6	0.050
ADS 13449	STF 2652	191940	20090+6205
	1982.5056	222.6	0.289
	1982.7651	222.4	0.296
	1983.4231	222.1	0.290
	1983.7155	223.0	0.294
	1984.7012	222.9	0.295
	1985.8370	221.5	0.300
ADS 13461	STT 400	191854	20102+4357
	1982.5056	56.1	0.176
	1982.7653	53.7	0.179
	1983.4258	47.7	0.179
	1983.7155	45.7	0.181
	1984.7012	36.2	0.191
	1985.8425	27.3	0.212
ADS 13508	A 282 AB	192124	20121+3429
	1983.7155	23.8	0.096
	1984.7012	24.9	0.086
	1985.8425	25.8	0.078
ADS 13493	Bu 1205	191841	20123-0805
	1983.4177	233.7	0.290
+22 3963	Cou 123	346003	20123+2248
	1983.7155	240.6	0.251
	1985.4901	239.8	0.245
ADS 13506	STF 2644	191984	20126+0052
	1982.7598	207.3	2.708
	1983.4286	208.0	2.664
HR 7735	31 Cyg	192577	20137+4644
	1985.8425	110.8	0.026
ADS 13564	A 1204	192559	20143+3129
	1983.7155	138.1	0.348
	1984.7039	138.9	0.352
	1985.4901	138.4	0.352
	1985.8425	137.4	0.351
ADS 13572	STT 403 AB	192659	20143+4206
	1983.4258	170.7	0.887
	1984.7012	171.1	0.885
+63 1608	MLR 60	193215	20153+6412
	1983.4176	341.4	0.206
	1983.7126	343.8	0.205
	1984.7012	344.3	0.184
	1985.8370	337.4	0.172
ADS 13611	A 2095 AB	192911	20156+4339
	1983.7155	159.7	0.170
HR 7755	CHARA 93	192983	20157+5014
	1985.8370	196.3	0.170
HR 7744	McA 60 Aa,B	192806	20158+2749
	1982.5057	141.6	0.240
	1983.4176	140.0	0.247
	1983.7156	140.1	0.250
	1984.7039	140.4	0.258
	1985.4901	140.3	0.266
HR 7744	CHARA 94 Aa	192806	20158+2749
	1985.4901	90°6	0"067
ADS 13660	BAR 11 AB	193238	20180+3311
	1983.4176	198.6	0.383
	1983.7156	199.4	0.37[illegible]
	1984.7012	198.4	0.36[illegible]
ADS 13686	A 1425 AB	193443	20189+3817
	1983.4176	270.2	0.135
	1983.7155	270.2	0.139
	1984.7012	268.6	0.140
	1985.4901	267.1	0.140
ADS 13777	A 288	194113	20232+2052
	1983.7156	198.8	0.110
+23 4004	Cou 125	194359	20244+2417
	1982.7596	115.2	0.364
	1983.4231	114.8	0.359
	1983.7156	114.7	0.363
+54 2344	MLR 588	194719	20246+5527
	1983.4259	234.5	0.194
	1983.7128	236.0	0.195
	1984.7012	234.9	0.200
-09 5457	RST 4062	194233	20247-0846
	1983.4231	357.6	0.263
+60 2125	MLR 503	194932	20250+6118
	1983.4259	33.2	0.169
	1983.7126	32.8	0.171
ADS 13850	A 730	194882	20251+5935
	1982.7651	324.5	0.221
	1983.4287	323.2	0.216
	1984.7012	322.5	0.218
+59 2231	MLR 433	194933	20253+6001
	1983.4259	147.3	0.233
	1983.7126	147.3	0.228
	1984.7012	147.9	0.232
HR 7801	CHARA 97	194215	20254-2840
	1983.4258	9.9	0.121
+33 3914	Cou 1956	195102	20281+3353
	1983.4259	235.6	0.305
	1983.7128	236.8	0.310
	1984.7013	236.5	0.310
-2416056	CHARA 98	194810	20285-2410
	1983.4258	81.8	0.234
ADS 13887	SHJ 323 AB	194943	20289-1750
	1983.4258	26.5	0.754
+26 3915	Wor 9 AB	------	20302+2651
	1982.7596	316.1	1.007
HR 7837	Fin 336	195330	20309-1503
	1982.5057	214.4	0.109
	1983.4231	212.1	0.108
ADS 13944	A 1675	195481	20311+1548
	1985.8479	206.0	0.065
ADS 13946	CHARA 99 Aa	195482	20312+1116
	1983.7128	124.9	0.324
ADS 13946	DA 1 BC	195482	20312+1116
	1983.4231	289.0	0.117
ADS 13989	Bu 671	196065	20317+6227
	1983.4259	319.1	0.469
	1983.7126	318.8	0.471
ADS 13961	See	195536	20325-1636
	1983.4231	123.9	0.242
+49 3310	McA 61	196089	20331+4950
	1984.7012	102.9	0.041
HR 7866	WRH AB	196093	20339+3515
	1982.5057	96.1	0.264
	1983.7128	97.2	0.280
	1984.7013	98.1	0.281
	1985.4847	97.2	0.283
ADS 14073	Bu 151 AB	196524	20375+1436
	1982.5057	18.1	0.401
	1982.7596	20.1	0.387
	1983.4259	25.7	0.345
	1985.4929	57.7	0.211
	1985.8479	67.7	0.191

TABLE IV. (continued)

ADS 14099	Hu 200 AB	196662	20393-1457
	1982.5057	111°0	0″328
	1982.7598	110.8	0.343
	1983.4258	110.2	0.339
+04 4510	Kui 99	196795	20396+0458
	1982.7598	122.9	0.356
	1983.4258	114.6	0.417
	1985.4929	124.6	0.632
ADS 14126	STT 410 AB	197018	20396+4036
	1983.4259	6.9	0.800
	1984.7012	7.4	0.799
HR 7906	α Del Aa	196867	20397+1556
	1985.4929	301.6	0.120
	1985.8534	292.3	0.132
ADS 14141	A 747 AB	197117	20397+4735
	1983.4259	108.7	0.295
	1983.7156	109.7	0.297
	1984.7012	109.4	0.309
	1985.8396	108.7	0.301
ADS 14148	A 2795	197075	20406+2156
	1983.4231	254.5	0.214
	1983.7128	254.8	0.219
	1985.4902	253.6	0.229
HR 7922	McA 62	197226	20410+3905
	1982.5056	97.2	0.102
	1984.7013	100.4	0.086
	1985.4847	98.4	0.081
+18 4585	Cou 226 AB	197229	20419+1931
	1983.4231	21.1	0.298
	1983.7128	22.1	0.298
-06 5567	RST 4679	197436	20440-0557
	1983.4231	358.6	0.300
	1983.7128	359.1	0.309
	1985.4902	358.6	0.315
ADS 14238	Bu 64 AB	197683	20451+1244
	1983.4231	162.9	0.605
	1983.7128	163.5	0.608
ADS 14274	CHARA 100 Aa	197989	20462+3358
	1983.4340	180.0	0.067
HR 7958	Kui 101	198151	20466+4632
	1985.8396	108.5	0.377
ADS 14296	STT 413 Aa,B	198183	20474+3629
	1982.5056	15.9	0.795
	1982.7571	16.1	0.797
	1983.4232	16.4	0.790
	1983.4340	16.5	0.787
	1983.7128	17.1	0.790
	1984.7013	17.2	0.801
ADS 14306	Bu 268	198253	20476+4204
	1983.4177	202.9	0.422
	1984.7013	204.1	0.413
ADS 14333	J 194 AB	------	20494+1124
	1982.7596	199.7	0.750
ADS 14360	STF 2729 AB	198571	20514-0537
	1983.4314	12.9	0.978
	1984.7118	14.0	0.986
	1985.4929	13.7	0.987
ADS 14379	Ho 144	198810-1	20523+2008
	1983.4232	348.1	0.317
	1983.7128	348.6	0.319
HR 7990	McA 64	198743	20527-0859
	1983.7128	123.7	0.196
ADS 14404	Ho 146	199071	20536+3514
	1983.4232	50.8	0.350
	1984.7013	51.1	0.338
ADS 14412	A 751	199306	20538+5919
	1982.5056	160.3	0.134
	1982.7651	156.8	0.132
	1983.4177	152.8	0.134
	1983.7156	152.2	0.135
	1984.7013	147.4	0.137
	1985.4849	143.7	0.142
	1985.8396	142.0	0.144
ADS 14493	A 756 AB	199937	20577+5850
	1983.4177	216°1	0″532
	1985.4849	215.3	0.548
	1985.8396	214.9	0.550
ADS 14504	STF 2741 AB	199955	20586+5028
	1982.7543	26.8	1.891
	1983.4287	27.1	1.866
ADS 14499	STF 2737 AB	199766	20591+0418
	1983.4287	285.3	0.964
ADS 14526	McA 65 Aa	200120	20598+4732
	1982.7651	56.9	0.211
	1983.4340	55.6	0.204
	1984.7040	54.5	0.201
HR 8038	Kui 102	199942	21002+0731
	1982.5057	65.0	0.255
	1982.7598	62.7	0.273
	1983.4287	60.6	0.283
	1985.4902	53.1	0.307
ADS 14543	A 1438	200222	21010+4000
	1983.4177	248.3	0.294
	1984.7013	248.9	0.299
+23 4216	Cou 128	200290	21019+2340
	1982.7596	135.4	0.188
	1983.4232	135.5	0.184
ADS 14575	STF 2751	200614	21022+5640
	1983.4287	353.5	1.561
ADS 14565	See 435	200245	21032-2744
	1983.4314	297.6	0.256
ADS 14592	McA 66 Aa	200497	21041-0549
	1983.4340	173.2	0.057
HR 8060	Fin 328	200499	21044-1951
	1982.7627	149.0	0.306
	1983.4259	144.0	0.316
	1985.4902	133.8	0.364
ADS 14617	Hu 590	200927	21048+4902
	1983.7100	88.3	0.252
	1984.7014	86.9	0.248
ADS 14648	Bu 368 AB	201038	21075-0814
	1982.7627	272.5	0.240
	1983.4259	[illegible]6.8	0.237
ADS 14666	STT 527	201221	21080+0509
	1983.4232	139.9	0.203
	1983.7101	138.8	0.210
	1984.7040	137.1	0.214
+57 2295	MLR 590	202107	21114+5737
	1983.7100	19.2	0.175
ADS 14749	STF 2780 Aa,B	202214	21118+6000
	1982.5057	216.4	1.016
	1982.7599	216.3	1.023
	1983.4341	216.8	1.016
	1983.7100	217.7	1.010
	1984.7118	217.2	1.019
ADS 14749	McA 67 Aa	202214	21118+6000
	1982.5057	60.4	0.040
	1983.4341	37.1	0.048
	1983.7100	50.0	0.043
	1984.7118	40.0	0.048
ADS 14761	Hu 767	202128	21135+1559
	1982.5057	21.7	0.113
	1982.5085	21.2	0.107
	1982.7626	24.7	0.105
	1983.4259	30.2	0.107
	1983.4314	32.9	0.101
	1983.4341	33.4	0.096
	1983.7101	37.2	0.103
	1984.7040	49.1	0.091
	1985.4849	58.2	0.094
ADS 14783	H 48	202582	21137+6425
	1982.7599	255.1	0.470
	1983.4341	256.1	0.445
	1983.7156	256.8	0.441
	1984.7040	257.6	0.413

TABLE IV. (continued)

ADS 14784	STF 2783	202519	21141+5818
	1982.7599	7°1	0".734
	1983.4341	7.0	0.735
	1984.7013	6.9	0.727
ADS 14773	STT 535 AB	202275	21145+1001
	1982.5059	38.2	0.132
	1982.7600	32.5	0.184
	1983.4232	27.6	0.281
	1983.4341	27.4	0.283
	1983.7101	26.8	0.304
	1984.7040	21.8	0.299
	1985.4849	15.6	0.210
	1985.4929	15.5	0.210
ADS 14775	A 883 AB	202260	21146-0050
	1983.4314	59.3	0.128
	1985.8535	46.9	0.120
ADS 14787	AGC 13 AB	202444	21147+3802
	1982.7599	120.0	0.653
	1983.4314	113.0	0.610
	1983.7101	110.2	0.600
ADS 14798	A 1692	202642	21152+5531
	1983.4315	154.1	0.326
	1983.7100	155.8	0.314
+30 4393	Cou 1183	202882	21180+3049
	1983.4259	22.7	0.194
	1983.4314	20.5	0.200
	1983.7100	20.7	0.204
	1984.7014	20.8	0.201
	1985.4902	20.8	0.206
ADS 14839	Bu 163 AB	202908	21187+1134
	1982.5031	247.9	0.261
	1982.7600	245.0	0.261
	1983.4314	245.3	0.213
	1983.7156	246.5	0.197
	1984.7040	242.5	0.125
	1985.4929	230.0	0.124
HR 8164	------	203338	21193+5838
	1984.7013	117.1	0.092
ADS 14889	STT 437 AB	203358	21208+3228
	1982.5057	25.0	2.202
	1982.7626	25.0	2.213
ADS 14894	STT 435	203323	21214+0254
	1983.4314	233.2	0.642
	1983.7101	234.1	0.643
	1984.7040	234.3	0.655
	1985.8480	235.2	0.624
ADS 14893	A 617	203345	21214+1021
	1982.5032	273.4	0.162
	1982.5059	272.7	0.167
	1983.4259	265.5	0.165
	1983.4314	269.2	0.161
	1983.7101	264.6	0.157
	1984.7040	255.8	0.107
ADS 14944	A 765 AB	203938	21238+4710
	1983.4314	30.5	0.420
	1983.7100	31.0	0.421
	1984.7040	30.4	0.425
ADS 14954	Bu 164 AB	203943	21251+0923
	1983.4314	211.1	0.183
	1983.7101	213.9	0.179
	1984.7040	212.8	0.173
	1985.8480	208.7	0.168
+17 4577	Cou 430	203991	21252+1828
	1982.7626	234.8	0.610
	1983.4314	234.8	0.598
	1984.7040	236.4	0.603
+28 4085	Cou 940	204051	21253+2928
	1983.4259	277.4	0.330
	1983.4314	276.9	0.324
	1983.7101	276.0	0.328
	1984.7040	277.1	0.334
	1985.8480	275.3	0.327
HR 8238	β Cep Aa	205021	21288+7034
	1982.5031	49°6	0".156
	1982.5057	50.8	0.151
	1982.7599	51.5	0.159
	1983.4259	51.4	0.151
	1983.4341	50.9	0.144
	1983.7100	52.1	0.146
	1984.7013	51.5	0.129
	1985.4849	51.8	0.121
ADS 15007	STF 2799 AB	204509	21289+1105
	1983.4314	268.6	1.744
ADS 15058	A 771	205085	21315+4817
	1983.7129	69.2	0.079
ADS 15070	A 2290	205064	21328+0200
	1983.7129	262.4	0.482
ADS 15103	STT 442	205599	21340+6148
	1983.4341	328.1	0.269
	1983.7130	327.6	0.263
ADS 15115	Hu 371	205541	21354+2427
	1982.5057	297.0	0.277
	1982.7572	295.5	0.289
	1982.7626	295.3	0.286
	1983.4314	295.8	0.288
	1983.7129	296.3	0.289
	1984.7014	296.9	0.291
	1985.8480	297.3	0.298
ADS 15131	Ho 463	205731	21362+4253
	1983.7129	174.8	0.433
ADS 15176	Bu 1212 AB	206058	21395-0003
	1982.7627	243.3	0.351
	1983.7129	246.9	0.371
	1985.8480	252.2	0.403
+08 4714	CHARA 105	206155	21400+0911
	1983.7129	131.6	0.252
ADS 15236	Hu 280	206512	21423+0554
	1983.7129	133.6	0.197
	1984.7040	135.4	0.196
	1985.8480	136.7	0.199
HR 8300	Kui 108	206644	21425+4106
	1982.5057	53.5	0.156
	1982.5084	53.5	0.163
	1982.7599	50.6	0.163
	1983.4341	46.2	0.166
	1983.7129	44.6	0.169
	1985.4904	31.2	0.187
	1985.8479	28.0	0.188
ADS 15251	Bu 688 AB	206656	21426+4103
	1983.7129	206.4	0.315
	1985.4904	205.1	0.330
	1985.8479	204.9	0.334
ADS 15281	Bu 989 AB	206901	21446+2539
	1982.5057	241.1	0.105
	1982.5085	234.1	0.101
	1982.7544	221.2	0.090
	1982.7600	225.0	0.098
	1983.4341	177.4	0.091
	1983.7129	163.7	0.104
	1984.7014	137.2	0.167
	1985.4929	125.8	0.219
	1985.8480	122.7	0.237
+34 4540	Cou 1484	207663	21498+3455
	1983.7129	354.2	0.331
	1984.7014	353.4	0.336
HR 8344	Cou 14	207652	21502+1718
	1982.5057	26.8	0.248
	1982.5085	26.1	0.248
	1982.7600	27.9	0.252
	1983.7129	36.8	0.267
	1984.7041	43.0	0.310
	1985.4902	46.8	0.322
	1985.8372	48.0	0.319
ADS 15375	Ho 170	207782	21505+3925
	1983.7129	239.2	0.307
	1984.7014	239.5	0.306

TABLE IV. (continued)

ADS 15407	STF 2843 AB	208132-3	21516+6545
	1983.4341	144.8	1.494
	1983.7130	144.8	1.496
	1984.7118	145.3	1.480
HR 8355	Fin 358	208008	21535-1019
	1985.8535	94.2	0.091
ADS 15435	A 620	208341	21540+4403
	1983.7129	278.2	0.336
ADS 15478	A 622	208610	21572+1047
	1983.7129	301.8	0.162
	1984.7041	299.5	0.153
ADS 15499	Bu 275	208905	21573+6117
	1982.7599	172.1	0.404
	1983.4341	172.3	0.398
	1983.7130	172.5	0.397
	1983.7157	172.3	0.398
	1985.8481	171.1	0.402
ADS 15530	Hu 774	209103	21598+4908
	1983.7129	136.5	0.167
	1984.7041	139.2	0.167
ADS 15549	A 1451	209260	22012+3915
	1985.4849	7.0	0.307
ADS 15578	Bu 694 AB	209515	22030+4439
	1985.8481	4.9	0.933
ADS 15600	McA 69 Aa	209790	22037+6437
	1983.4341	213.9	0.041
ADS 15599	Bu 696 AB	209622	22045+1552
	1984.7041	4.1	0.171
	1985.8372	4.0	0.183
+81 0767	MLR 257	210979	22062+8240
	1983.7157	244.1	0.206
+25 4577	Cou 537	------	22077+2622
	1984.7041	29.3	0.168
+22 4563	Cou 136	210444	22100+2308
	1982.7654	44.5	0.398
	1984.7041	44.3	0.409
	1985.4904	42.1	0.421
	1985.8372	42.4	0.420
HR 8455	CHARA 106	210460	22103+1937
	1985.8373	9.0	0.465
ADS 15746	Hu 695	------	22129+5058
	1983.7157	15.4	0.788
ADS 15756	Bu 991	211113	22136+5234
	1983.7157	138.5	0.643
	1984.7041	138.4	0.638
	1985.8481	137.9	0.648
ADS 15758	McA 70 Ab	211073	22139+3944
	1982.5059	7.8	0.463
	1985.4849	8.7	0.471
ADS 15758	Bnu Aa	211073	22139+3944
	1982.5059	54.0	0.188
+20 5138	Cou 139	------	22236+2051
	1985.4904	70.1	0.390
HR 8538	CHARA 108	212496	22236+5214
	1984.7041	167.4	0.219
ADS 15896	STF 2900 AB	212395	22237+2051
	1985.8481	5.0	0.303
ADS 15902	Bu 172 AB	212404	22241-0451
	1982.5060	258.4	0.162
	1982.7653	253.7	0.169
	1985.8425	212.2	0.122
+39 4837	Cou 1642	212900	22268+4034
	1985.8425	76.1	0.159
ADS 15971	STF 2909 AB	213051-2	22288-0002
	1982.5059	218.6	1.600
	1982.5085	218.7	1.632
	1982.7544	218.4	1.664
	1982.7654	218.5	1.657
	1985.8483	212.3	1.728
HR 8572	McA 71	213310	22295+4743
	1982.5059	43.3	0.132
	1985.4849	46.3	0.119
ADS 15988	STF 2912	213235	22299+0425
	1984.7068	116.5	0.712
	1985.8483	116.6	0.682
ADS 16011	Hu 981	213530	22306+6138
	1982.5059	222.9	0.315
	1982.7654	222.6	0.313
	1983.7157	223.4	0.309
+17 4759	Cou 234	213392	22307+1758
	1984.7041	327.2	0.147
	1985.4904	324.6	0.151
	1985.8425	322.7	0.152
+53 2911	Kui 112 Aa	------	22327+5347
	1984.7069	225.0	0.557
ADS 16057	STF 2924 AB	213973	22329+6954
	1982.7654	90.3	0.444
	1983.7157	91.3	0.433
	1984.0573	91.2	0.424
	1985.8535	92.4	0.407
ADS 16072	Hu 983	214051	22339+6550
	1985.8535	214.2	0.083
ADS 16073	A 1468	213990	22342+5405
	1983.7157	256.1	0.275
	1984.7042	256.7	0.273
	1985.8481	254.6	0.276
ADS 16098	A 1470	214222	22357+5312
	1985.8481	290.9	0.117
ADS 16111	Bu 1092 AB	214511	22361+7252
	1983.7157	234.6	0.274
	1984.7042	238.0	0.257
	1985.8536	239.3	0.239
+68 1319	CHARA 113	214606	22373+6913
	1983.7158	3.1	0.487
HR 8617	CHARA 114	214558	22383+4511
	1985.8535	119.9	0.114
ADS 16130	A 2695	214448	22384-0754
	1984.7068	134.6	0.139
ADS 16138	Ho 295	214608	22387+4418
	1982.5059	334.0	0.189
	1982.7654	332.0	0.221
	1983.7102	332.8	0.244
	1984.0573	333.0	0.271
	1984.7042	333.8	0.293
	1985.4904	333.1	0.312
	1985.8425	333.4	0.330
+80 0731	McA 72	215319	22394+8123
	1983.7102	98.2	0.149
	1985.8373	94.9	0.151
ADS 16164	HO 188	214807	22402+3731
	1984.7042	202.9	0.317
	1985.8425	203.4	0.326
HR 8629	Kui 114	214810	22408-0333
	1982.7653	102.2	0.057
	1983.7101	120.2	0.121
	1984.7041	122.9	0.153
	1985.8425	124.3	0.197
ADS 16173	Ho 296 AB	214850	22408+1432
	1982.5059	329.4	0.121
	1982.7654	308.7	0.106
	1983.7157	213.0	0.075
	1984.7041	115.3	0.142
	1985.8481	92.8	0.248
ADS 16214	STT 476 AB	215242	22431+4709
	1982.7654	307.0	0.489
	1983.7157	306.8	0.482
	1984.0573	306.3	0.489
	1984.7042	305.9	0.487
	1985.8425	304.8	0.493
ADS 16214	Hu 91 BC	215242	22431+4709
	1985.8425	56.4	0.034
ADS 16249	Hu 783	215590	22453+5128
	1983.7102	181.8	0.193
	1984.7042	182.3	0.195
	1985.8481	182.2	0.195

TABLE IV. (continued)

ADS 16314	Ho 482 AB	216285	22514+2624
	1982.7654	37°5	0″347
	1983.7157	37.5	0.348
	1984.7042	36.3	0.352
	1985.4904	35.3	0.363
	1985.8427	34.7	0.361
HR 8704	McA 73	216494	22535-1137
	1985.4849	280.6	0.076
	1985.8536	279.4	0.079
+22 4742	Cou 240	216879	22564+2257
	1982.7544	289.8	0.712
+23 4640	Cou 542 Aa	216963	22570+2441
	1985.4904	142.8	0.119
	1985.8536	150.3	0.117
HR 8734	CHARA 116	217107	22583-0224
	1982.5060	164.0	0.457
ADS 16417	STT 536 AB	217166	22585+0922
	1982.5059	346.5	0.284
	1982.7654	346.3	0.320
	1983.7101	347.0	0.313
	1984.0573	346.9	0.311
	1984.7041	346.6	0.300
	1985.8427	345.9	0.279
ADS 16430	A 192	------	22589+4617
	1983.7157	236.4	0.529
	1984.7069	236.8	0.524
ADS 16428	STT 483	217232	22592+1144
	1982.5085	303.3	0.552
ADS 16469	STT 487	217992	23013+8046
	1983.7102	198.9	0.227
	1984.0573	201.6	0.221
	1984.7042	197.1	0.242
HR 8762	o And Aa	217675	23019+4219
	1984.7042	44.8	0.058
HR 8762	o And AB	217675	23019+4219
	1982.5059	358.6	0.280
	1982.7654	358.1	0.291
	1983.7102	357.1	0.275
	1984.7042	356.4	0.268
	1985.4904	355.0	0.266
ADS 16457	A 194	217712	23020+4800
	1983.7102	292.2	0.123
	1984.7043	292.5	0.124
ADS 16467	Bu 1147 AB	217782	23026+4245
	1982.5087	335.3	0.396
	1982.7655	337.0	0.385
	1983.7102	337.7	0.387
	1984.0601	335.9	0.385
	1984.7069	338.4	0.385
+63 1925	MLR 70	218179	23048+6405
	1983.7102	252.4	0.563
ADS 16497	A 417 AB	218060	23052-0742
	1985.8536	19.6	0.165
ADS 16505	A 196	218196	23055+4643
	1984.7069	315.7	0.462
GL 888	Wor 13	------	23060+4220
	1983.7157	156.7	0.835
ADS 16518	Bu 180 AB	218439	23072+6049
	1983.7102	144.0	0.559
	1984.7043	143.6	0.553
ADS 16530	Hu 994	218537	23078+6338
	1982.5060	310.4	0.200
	1982.7655	308.3	0.202
	1983.7157	308.0	0.207
	1984.0573	308.3	0.212
	1984.7042	308.6	0.210
HR 8817	RST 3320	218640	23099-2227
	1982.7655	318.1	0.270
ADS 16561	Bu 385 AB	218767	23103+3228
	1983.7102	92.9	0.631
	1984.7069	92.0	0.632
ADS 16576	Ho 197 AB	218917	23115+3813
	1983.7103	317°5	0″294
	1984.7043	317.1	0.287
	1985.8536	313.6	0.299
ADS 16591	A 2298	219018	23126+0242
	1985.8536	99.8	0.136
ADS 16638	Bu 992	219633	23164+6408
	1983.7102	43.2	0.258
	1984.0573	44.0	0.263
	1984.7042	41.1	0.261
ADS 16650	Hu 400	219675	23176+1819
	1983.7103	128.0	0.345
ADS 16672	McA 74 Aa	219834	23191-1327
	1982.5060	131.7	0.180
	1982.7654	148.9	0.193
+41 4751	Cou 1646	------	23198+4243
	1983.7158	46.2	0.171
+27 4530	Cou 439	219963	23199+2845
	1983.7103	209.1	0.216
	1985.8427	214.4	0.218
+33 4690	Cou 742	219982	23199+3444
	1983.7103	29.8	0.268
	1984.7069	30.0	0.265
	1985.8427	29.6	0.267
ADS 16708	Hu 295	220278	23226-1503
	1982.5087	103.8	0.370
	1985.8428	108.6	0.303
ADS 16731	STT 495	220562	23241+5732
	1982.5060	120.1	0.275
	1982.7655	119.0	0.289
	1983.7158	119.6	0.292
	1984.7043	119.4	0.295
	1985.8373	119.1	0.301
ADS 16748	Ho 489 AB	220723	23259+2742
	1983.7103	229.3	0.533
	1984.7069	228.9	0.530
	1985.8427	227.5	0.533
+22 4835	Cou 338	220794	23266+2342
	1985.8427	38.9	0.110
+41 4791	Cou 1847	221102	23288+4225
	1983.7103	40.1	0.113
	1984.7043	38.5	0.097
	1985.8374	33.0	0.099
ADS 16800	Bu 1266 AB	221264	23305+3050
	1982.5060	91.6	0.251
	1982.7655	89.6	0.251
	1983.7158	87.2	0.259
	1984.7043	84.1	0.268
	1984.7043	83.8	0.262
	1985.8427	80.3	0.263
ADS 16806	Bu 774	221333	23307+6420
	1983.7102	338.6	0.600
	1984.7069	338.8	0.593
	1985.8373	338.1	0.593
ADS 16819	Hu 298	221445	23322+0705
	1983.7103	115.1	0.147
	1985.8427	146.9	0.127
+22 4860	Cou 144	------	23339+2342
	1985.8427	57.0	0.329
ADS 16836	Bu 720	221673	23340+3120
	1982.5060	261.5	0.490
	1982.5087	261.2	0.491
	1983.7158	262.7	0.511
	1984.7069	263.2	0.509
	1985.8427	263.6	0.518
ADS 16858	Bu 721 AB	221925	23363-0707
	1983.7103	133.4	0.226
	1985.8428	135.0	0.240

TABLE IV. (continued)

ADS 16877	STT 500 AB	222109	23375+4426
	1982.5087	359°3	0″487
	1982.7655	357.6	0.484
	1983.7158	358.4	0.474
	1984.0574	358.7	0.476
	1984.0601	359.5	0.479
	1984.7069	358.8	0.472
	1985.8374	358.5	0.479
ADS 16904	A 643	222326	23392+4543
	1983.7103	165.2	0.226
	1985.8373	156.5	0.220
+45 4301	MLR 4	222516	23412+4613
	1983.7103	277.8	0.159
	1984.0574	278.2	0.156
	1985.8373	298.4	0.132
HR 9003	McA 75 Aab	223047	23460+4625
	1982.5060	107.3	0.279
	1982.7655	104.1	0.291
	1983.7103	104.5	0.284
	1985.8373	103.1	0.295
+35 5106	Cou 944	------	23485+3608
	1985.8536	98.1	0.187
ADS 17019	B 2547 AB	223331	23485+3617
	1983.7103	358.0	0.247
	1985.8536	358.8	0.237
ADS 17020	STT 507 AB	223358	23486+6453
	1982.5085	308.3	0.702
	1984.0574	307.2	0.700
	1984.7069	306.6	0.709
+18 5223	Cou 343	223402	23492+1915
	1983.7103	115.3	0.211
	1985.8427	117.0	0.206
ADS 17030	A 424	223486	23498+2740
	1982.7655	103.7	0.170
	1983.7103	106.6	0.173
	1984.0574	108.9	0.166
	1985.8427	110.3	0.171
ADS 17050	STT 510 AB	223672	23516+4205
	1983.7103	305.8	0.533
	1984.0574	305.9	0.523
ADS 17052	A 2700	223688	23517-0637
	1985.8427	114.6	0.134
HR 9041	Fin 359	223825	23529-0313
	1982.5060	42.7	0.106
	1982.7655	44.3	0.089
	1983.7103	37.0	0.084
	1985.4930	14.7	0.069
	1985.8428	10.8	0.059
+42 4792	Cou 1498	224167	23557+4318
	1983.7103	39.9	0.164
	1985.8428	39.0	0.164
ADS 17104	Hu 500	224219	23561+2327
	1985.8428	87.7	0.165
ADS 17111	A 2100	224315	23568+0443
	1983.7103	179.1	0.181
	1985.8428	163.7	0.146
ADS 17118	A 900	224395	23574+7251
	1983.7104	127.1	0.329
	1985.8429	127.2	0.337
−14 6588	RST 4136 AB	224512	23586-1408
	1983.7158	29.6	0.149
	1985.8428	24.5	0.172
ADS 17151	A 1498	224646-7	23594+5441
	1983.7104	84.5	0.386
	1984.0574	85.1	0.389
	1985.8428	84.3	0.389

Notes to TABLE IV.

The brief notes given below are presented primarily in connection with the newly resolved stars. The "binary types" indicated in Tables II and III are from a variety of sources, including the *Bright Star Catalog* (Hoffleit 1982), the catalog of spectroscopic binary star orbits of Batten *et al.* (1978), the catalog of composite spectrum stars compiled by Hynek (1938), and the catalog of lunar-occultation binaries of Evans (1983). Additional occultation binary candidates were added to the observing program from lists published by the International Occultation Timing Association (IOTA) and from the list of stars exhibiting anomalous occultations published by Appleby (1980).

HD 761 = CHARA 1: This pair is confirmed by Tokovinin (1985) and is steadily closing in separation.

HD 8272 = ADS 1105: STF 115 AB, first measured by F. W. Struve in 1836 at an angular separation 0″68, had opened to 1″2 by 1910, then steadily closed to 0″35 at the time of the first speckle measurement in 1978 (McAlister and Hartkopf 1984). Based on a preliminary visual/speckle orbit, the pair reached an apparent minimum separation of 0″01 in the spring of 1984.

HD 11031 = CHARA 4: Although this new component is indicated as Aa, we have not yet firmly established whether it is associated with the A or B component of the 1″9 system comprising ADS 1438.

HD 13520 = CHARA 5: The five negative results obtained during 1976–1980 (McAlister and Hartkopf 1984) are apparently due to a large magnitude difference.

HD 15089 = CHARA 6: Heintz (1962) found a submotion to the visual orbit of ADS 1860 AB ($P = 840$ yr, $a = 2″27$) with a period of 52 yr and an amplitude of 0″11. The component reported here may coincide with Heintz's astrometric component.

HD 21242 = CHARA 9: This is UX Ari, an RS CVn type binary that is not eclipsing. The spectrum shows three components (Fekel, private communication), two of which are identified with the 6.44 day system described by Carlos and Popper (1971) while the third is possibly the new component reported here.

Ross 29 = CHARA 15: Van Maanen (1941) suspected this star to be a binary, but these are the first measurements of a companion.

HD 58728 = McA 30: Fekel (private communication) has detected this system as a third component in the spectrum and makes a preliminary estimate of the period of 760 days.

HD 106760 = CHARA 37: A spectroscopic orbit with a period of 1300 days was determined by Christie (1936). This star has been observed by speckle interferometry on ten occasions during 1976–1981 at which no companion was seen. A large or variable magnitude difference may be present.

HD 114378-9 = ADS 8804: Nearly 40 speckle measurements have now been published for STF 1728 AB. A preliminary orbit for this nearly edge-on pair, based solely on speckle data, indicates that one of the F5 V stars may partially eclipse the other in early 1990. Observations over the next few years will permit a more accurate statement concerning this possibility.

HD 157482 = McA 47: Fekel (private communication) has an unpublished spectroscopic orbit for this system with a period of 5.5 yr.

HD 173495 = ADS 11640: This is a quadruple system consisting of two close (0″14) pairs of similar position angle discovered by Finsen with his eyepiece interferometer. Our 1982 speckle observations were made at a lower magnification and included all four stars in the field. The resulting overlapping autocorrelation peaks precluded us from measuring the Aab and Bab pairs directly but did permit the measurement of the AB, Aa-Bb and Ab-Ba configurations. In later observations made at a higher magnification, we observed the A and B components separately enabling the measurement of Aab and Bab but not AB.

HD 176155 = CHARA 82: Abt (1959) reported a spectroscopic orbit with a period of 1435 days for the primary component of the visual binary ADS 11884. The primary is a Cepheid variable with a period of 4.47 days. Continued observation of this system interferometrically and spectroscopically could permit the determination of the mass and distance for a Cepheid variable star.

HD 192806 = McA 60 Aa,B + CHARA 94 Aa: Speckle interferometry has now found two components to HR 7744 = 23 Vul.

HD 194215 = CHARA 97: The correspondence of this newly resolved component with the 377.6 day spectroscopic system reported by Bopp *et al.* (1970) can only be established by further observations.

HD 206155 = CHARA 105: Lacy and Popper (1984) discovered a previously unknown companion to the eclipsing binary EE Peg through its effects on radial velocity and times of primary eclipse. They find the third component to have a period of 1464 days and a mass ratio $M_{A+B}/M_C \simeq 5$–12. Their component would be expected to exhibit a separation from the primary of approximately 0″03, a value just resolvable by speckle interferometry. It thus seems likely that the object seen in our speckle observations is yet another long-period member of this system.

HD 221264 = ADS 16800: Fekel (private communication) reports that he has now detected four components in the spectrum of this star.

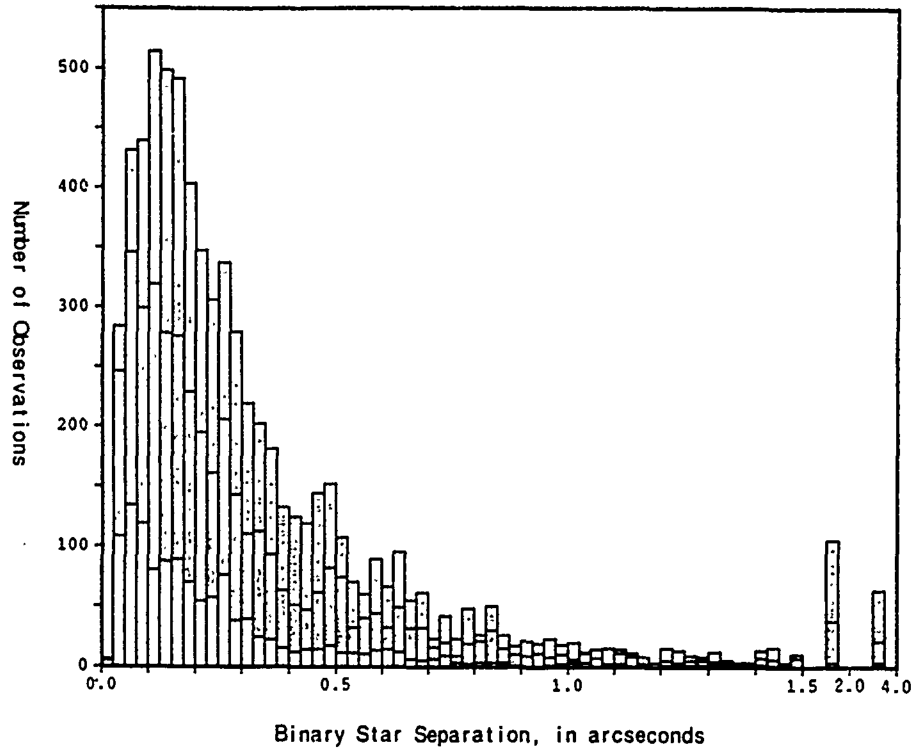

FIG. 5. The distribution of measured angular separations is shown for all modern interferometric observations of binary stars that are known to and catalogued by the authors. For the 6910 measurements represented here, 2908 are from our ICCD camera (light shading), 2780 are from our original photographic speckle program (dark shading), and 1222 measurements have been accumulated by other programs of binary star interferometry (unshaded). The overall mean angular separation in the collected data is 0"35, while 17% of the measurements are for binary stars with separations less than or equal to 0"10.

ate quadrants for known visual binaries, but we arbitrarily adopt $\theta < 180°$ for newly resolved pairs.

The 2780 measurements of 1012 systems in Table IV combine with the same number of measurements published from our photographic speckle program and the 128 measurements from Paper I to give a total of 5688 speckle measurements of binary stars resulting from the GSU program. At the time of submission of this paper, we are aware of another 1222 measurements from other modern interferometric programs giving a total of 6910 interferometric observations of binary stars.

The mean angular separation of the observations in Table IV is 0"409. This compares with a mean value of 0"333 for our earlier photographic results. The larger mean is at least partly due to the exclusive use of the microscope objective giving a scale of 0.0161 arcsec per pixel during our first few observing runs with the new camera at the 4 m telescope. Such a scale gives only slightly more than 2 pixels per Airy disk, a sampling interval too small to reach the diffraction limit. This approach was corrected for later observations, and we now use the 10× microscope objective only when seeing conditions are very poor or when binaries with angular separations of the order of 1 arcsec or wider are being observed. In Fig. 5 we show the distribution of observed angular separations for the data from this paper and Paper I, from the GSU photographic speckle series, and from all other contributors known to us. The mean angular separation in these collected measurements is 0"349, and 17% of the results are for angular separations no larger than 0"10.

Many people have made invaluable contributions to this program, and we wish to acknowledge their efforts here. The detailed design and construction of the new speckle camera was carried out by William G. Robinson, and the camera's reliability and efficiency are testimony to a superb job. The vector autocorrelator, designed and constructed by Peter Vokac, has made it possible to reduce efficiently nearly one terabyte of data. The cooperation and enthusiasm of the KPNO LTOs have been particularly important to the efficient use of telescope time, and we thank Hal Halbedel, Barbara Schaefer, Dean Ketelson, George Will, Bret Goodrich, Annie Shaw-Hansen, Randy Bergeron, and Dean Hudek for keeping their good spirits during many nights of 3 min repointing cycles. We have also benefitted greatly from the granting of long-term observer status at the KPNO 4 m telescope during the course of these observations and express our appreciation to several understanding TACs who continued to grant time while we were developing the reduction and analysis procedures. Assistance in gathering data at the telescope or in handling the data in the laboratory has been given by Barbara Gaston, Dick Miller, Phillip Lu, Ed Dombrowski, Mike Carini, and Alex Rosen. Assistance in computer matters at GSU has been given by Paul Schmidtke, Mike Lucas, Duke Windsor, and Steve Lasseter. We are grateful to Wayne H. Warren, Jr., of the Astronomical Data Center at the NASA Goddard Space Flight Center for providing information incorporated in object identification. We thank Frank Fekel for his many suggested candidate stars and for his comments on this paper. Occultation binary candidates have been kindly recommended by Nat White and David Dunham. We thank Art Hoag for making time available on the Lowell 24 in. refractor, and Ralph Nye for quickly preparing a mounting bracket so that our camera could be used experimentally on that telescope. Finally, we are especially indebted to Charles Worley, who, in addition to providing valuable advice over the years, proofread our entire list of measures and pointed out a number of identification errors. Our new measurements are already incorporated in the Washington Double Stars Catalog maintained by Mr.

Worley at the U.S. Naval Observatory. The ICCD speckle camera system was funded by the National Science Foundation through grant AST-79-24576, while the continuing research effort has been supported by NSF grants AST 80-15781 and AST 83-14148. The image-processing and computer system was purchased through a DOD-University Research Instrumentation Program grant administered by the Air Force Office of Scientific Research as grant AFOSR 83-0257. O.G.F.'s participation in this effort has been made possible through a subcontract with GSU funded by the Air Force Office of Scientific Research through grant AFOSR 81-0161.

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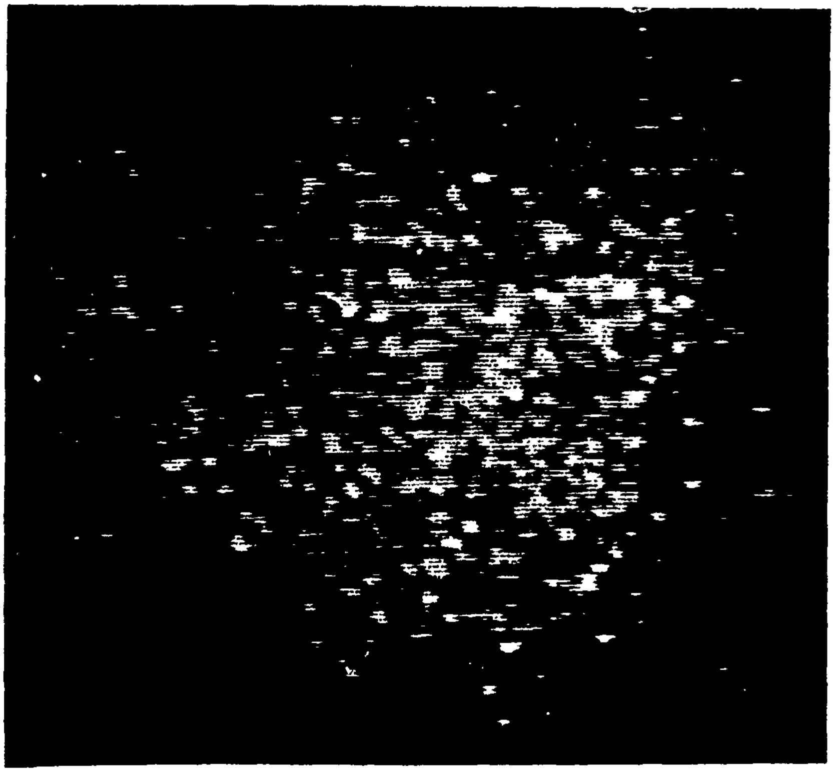

FIG. 2. A single speckle frame of the visual binary stars ADS 7158 (κ UMa) obtained at the 4 m KPNO telescope with the GSU ICCD speckle camera on 1985.835 is shown. The field of view is approximately 2.0 arcsec square.

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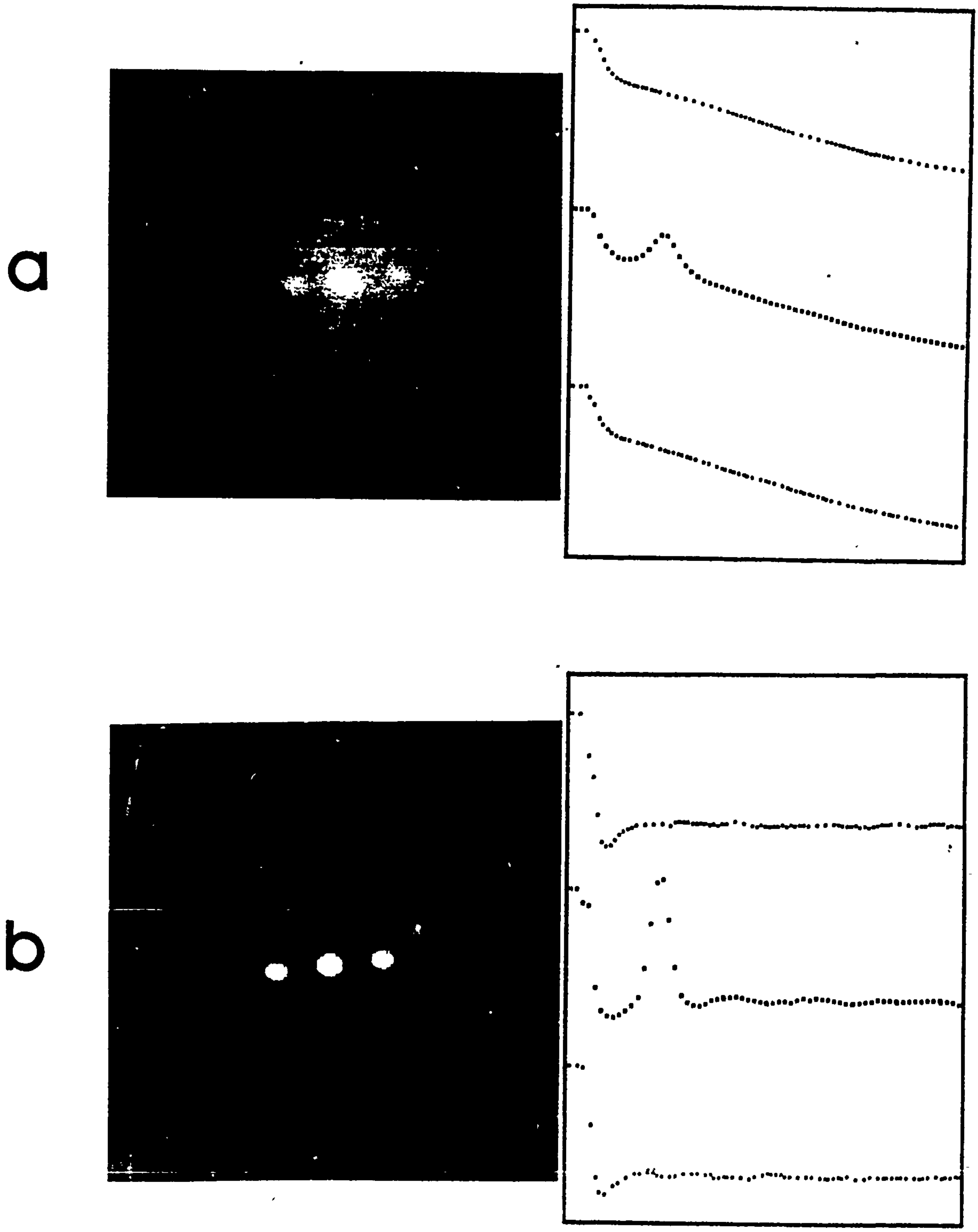

FIG. 3. (a) The composite vector autocorrelogram of approximately 1800 speckle frames of ADS 7158 shows the characteristic peaks indicative of duplicity superimposed upon a seeing-dominated background. (b) A background-subtracted version of the same autocorrelogram shows the resulting high-contrast double star peaks on either side of the strong zeroth spatial component.

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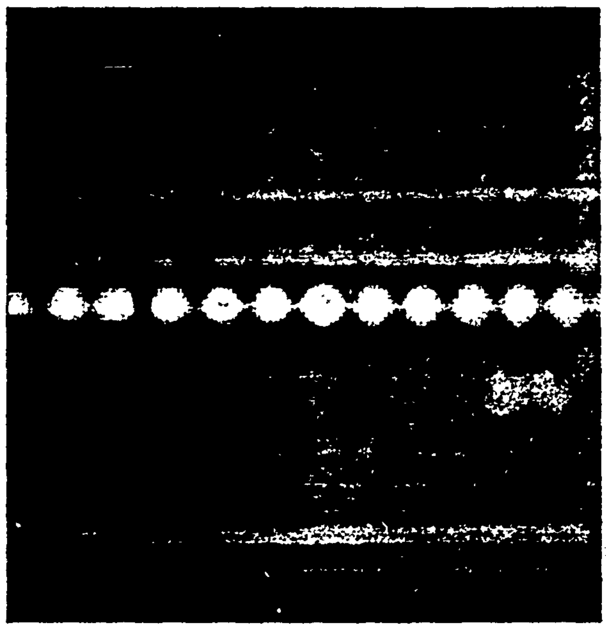

FIG. 4. A vector autocorrelogram of calibration data obtained on 1984.387 for the single star κ CrB observed through a double-slit aperture mask shows the high-signal-to-noise row of peaks used to determine the image plane scale and pole orientation.

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ICCD SPECKLE OBSERVATIONS OF BINARY STARS. III. A SURVEY FOR DUPLICITY AMONG HIGH-VELOCITY STARS

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ABSTRACT

A survey program to identify binary candidates among high-velocity dwarf stars using the GSU speckle camera has been carried out. The purposes of this study are: (1) to determine the binary frequency of the halo population to provide information on the star-formation processes in the galactic halo; and (2) to eventually derive the orbital elements of the newly discovered binaries. Our angular-resolution limit of 0.03″ corresponds to a linear separation of 3 AU at a distance of 100 pc. If a sufficient number of halo binaries are found, then the halo mass–luminosity relation can be derived. Finally, with the help of stellar-interior models, it may be possible to determine the helium abundance of the component stars. Such determinations would set an upper limit to the primordial helium abundance. In this paper, we report speckle interferometry data that have been obtained and analyzed for a sample of 182 stars. Based on these data, ten stars are found to be binary. Of these ten, four are newly resolved systems and six are rediscoveries of previously known binaries. These data imply a duplicity frequency of 6% for the stellar sample in our list. However, this frequency must be corrected for observational selection effects which limit binary detection to stars with $V < 10.5$, with angular separation between 0.03″ and 1″, and $\Delta m < 3.0$ mag. After applying these corrections, we find that our data are compatible with a total frequency for high-velocity long-period doubles as large as for low-velocity stars. Distances have been estimated for the ten binary stars using their spectroscopic parallaxes and visual magnitudes. Of these ten stars, all are within 100 pc of the Sun and eight have linear separations < 20 AU. Using the mass–luminosity relation and assuming circular orbits, four stars are found to have periods less than 20 yr. These ten candidates will be monitored to determine their orbital elements.

I. INTRODUCTION

The nature of the binary population among halo stars has been the subject of interest for numerous investigations. Through the study of these systems, one can determine their orbits and the masses of the components. Currently, there is no available direct mass measurement for a single star among high velocity (and, presumably, halo population) stars. A knowledge of the mass–luminosity relation for main-sequence stars in the galactic halo would first enable us, with the help of appropriate stellar models (Mengel *et al.* 1979), to evaluate the helium abundances and provide a reliable upper limit to the primordial helium abundance Y_p (Demarque 1966; Demarque and McClure 1977; Carney 1983b; Cole, Demarque, and Green 1983).

Secondly, a determination of the dependence of the mass–luminosity relation for halo dwarfs upon metallicity would, in principle, yield the enrichment ratio $\Delta Y/\Delta Z$ due to Population III stars within the galactic halo prior to the formation of the currently observed Population II stars. This quantity is of fundamental importance for the study of galactic chemical evolution and enrichment (Larson and Tinsley 1978; Matteucci and Chiosi 1983; Peimbert 1983; Searle 1984).

Finally, the observations would also provide a test of the frequency of binary systems among halo-population stars. This frequency remains uncertain in comparison to that of the main-sequence stars of low velocity.

In a study of the frequency of spectroscopic binaries among Population II stars, Abt and Levy (1969, 1976) concluded that short-period binaries are rare among all high-velocity dwarfs and metal-poor stars. Crampton and Hartwick (1972) have confirmed the low frequency of short-period spectroscopic binaries in the halo population. On the other hand, Partridge (1967) investigated nearby high-velocity stars and concluded that if visual and spectroscopic binaries are considered, the duplicity rate is independent of stellar velocity. Based on *uvbyUBVRIJHK* photometry, Carney (1983a, 1984) has suggested that the halo dwarf binary frequency may be as high as 20%–25% using metallicity-insensitive blue versus infrared color indices.

For giant stars, Gunn and Griffin (1979) first studied the globular cluster M3 using a high-precision radial-velocity spectrometer and found no spectroscopic binaries. Subsequently, Harris and McClure (1983) reported their finding of a fairly high frequency of binaries (15%–20%) in a DAO survey of field giants. Spectroscopic binaries are now being found in the field halo population by numerous investigators: Mayor and Turon (1982), McClure *et al.* (1985), Ar-

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deberg and Lindgren (1985). In the globular cluster M3, the giant von Zeipel 164 has also been identified as a binary by Latham, Hazen, and Pryor (1985). Finally, a speckle-interferometry survey of 672 stars (426 dwarfs and 246 evolved stars) from the Yale *Bright Star Catalogue* (Hoffleit 1982) by McAlister *et al.* (1987a, Paper I) has shown a frequency of 11% in the separation range 0.04"–0.25".

The multiplicity fraction of other stellar populations is typically between 10% and 40% for the field F3–G2 dwarf and giant stars (Abt 1979, 1983). This includes the Hyades main-sequence stars (Mathieu, Stefanik, and Latham 1985), the giants in open clusters (Mathieu 1985; Harris and McClure 1985), and the supergiants (Burki and Mayor 1984). From a survey of 900 F, G, and K stars selected from the Lowell Proper Motion Catalog, Carney and Latham (1987) recently reported a frequency of 25% for these stars.

A new survey program to identify binary candidates among high-velocity dwarf stars using the Georgia State University (GSU) speckle camera has been carried out. A list of approximately 700 dwarf stars whose radial velocities are larger than ± 65 km/s was selected from Roman (1955), Eggen (1964), and Abt and Biggs (1972). Various other lists of radial velocities published since 1972 were also searched. Since the lists are numerous, the references quoted hereafter are for the major and latest publication only. These lists include Andersen and Nordstrom (1983a,b), Andersen *et al.* (1985), Beavers *et al.* (1977,1979), Fehrenbach and Burnage (1982,1984), Lu (1983), Lu and Lee (1983), McClure *et al.* (1985), and Carney and Latham (1987). Although the list initially included all stars of luminosity class V, only 452 stars north of declination $-20°$ and magnitude brighter than 10.5 were included in an observing list used at the 4 m Mayall telescope at Kitt Peak.

Binary survey programs for halo-population stars currently in progress, other than this study, are those by Carney (1983b, 1984), using photometric metallicity indicators, and Carney and Latham (1987), based primarily on high-proper-motion objects with the digital stellar speedometer of the CfA (Latham 1985).

II. SPECKLE OBSERVATIONS

Speckle-interferometry data have been obtained for 182 high-velocity stars in this program, of which 39 stars were observed twice, using the GSU speckle camera at the 4 m telescope at KPNO. Reviews of speckle interferometry have been published by Labeyrie (1970, 1978) and Worden (1977). The camera system and observational procedures employed in this survey are identical to those described by McAlister *et al.* (1987b, Paper II). All data reduction and analysis was carried out at the Center for High Angular Resolution Astronomy (CHARA) at GSU. Preliminary results of this survey have been reported earlier (Lu *et al.* 1986). This study has shown that ten stars (six with two speckle observations) are definitely halo binaries.

Tables I and II contain measurements of four newly resolved and six previously known binary stars, respectively. Newly resolved stars have been given a "CHARA" designation consistent with the naming procedure initiated in Paper II. The measured angular separations range from 0.035" to 0.302" for the newly resolved stars and 0.147" to 1.088" for the known binaries. The position angles in Tables I and II are subject to a 180° ambiguity, since autocorrelated speckle observations cannot provide the true quadrant in which the secondary star lies.

Table III contains 172 stars that were observed in the survey, many with two speckle observations, for which no convincing evidence of duplicity was detected in the autocorrelograms. The effective field of view of the autocorrelator address window was limited to a rectangle of 1.22"×2.44" centered on the primary stars. Thus the upper limit to an angular separation in the survey was about 1"; the lower limit of the angular separation was about 0.035", the diffraction limit of the 4 m Mayall reflector. Those stars with negative results may belong to one or more of the following three cases, namely: (a) their separations are either less than the diffraction limit of 0.035" or greater than the address window of the autocorrelator, thus being undetectable using current speckle data; (b) the magnitude difference is more than 2.5 mag; or (c) they are single stars.

III. DISCUSSION

a) Binary Frequency

The ten stars listed in Tables I and II lead to a binary frequency of about 6%. This binary frequency of 6% is not, however, representative of the total binary frequency among high-velocity stars. The GSU speckle interferometer only detects binary candidates with $V < 10.5$ and angular separation between 0.035" and 1". The magnitude difference Δm between primary and secondary must also be less than about 2.5 mag. We must therefore correct for each of these selection effects.

(1) The first selection effect ($V < 10.5$) changes the maximum distance reached by our survey for stars of different absolute magnitudes. If we consider only dwarf stars, this distance is a function of spectral type only, and can easily be evaluated.

(2) The second selection effect concerns the restriction that the angular separation must be between 0.035" and 1.0" for stars to be detected. Given an angular separation, the corresponding detectable orbit size depends linearly on distance. Therefore, given the distance of a star, one can calcu-

TABLE I. Newly resolved systems.

CHARA Number	Name	HD Number	α,δ (2000)	V Mag.	Spectral Classif.	Epoch	Theta	Rho
117	+57 0730	21794	03337+5752	6.36	F7V	1985.8433	154.5	0.099
118	+09 4369	189711	20011+0931	8.43	NOV	1985.4928	199.5	0.221
						1985.8372	174.4	0.302
119	+17 4708	G 126-62	22115+1806	9.48	F6VI	1985.8372	126.7	0.205
120 Aa	+57 2787	222794	23434+5804	7.1	G0	1985.8536	154.3	0.057

TABLE II. Measures of previously known systems.

ADS Number	Disc. Name	HD Number	α, δ (2000)	V Magnitudes		Spectral Classifications		Epoch	Theta	Rho
5469	A 2731	49409	06486+0738	8.4	9.0	G0V		1985.8408	58.1	1.088
9397	A 2983	130669	14493+1014	9.2	9.2	K2V		1985.4895	152.4	0.150
								1985.4978	152.1	0.147
9716	STT 298 AB	139341	15361+3948	7.5	7.6	K2V		1985.4841	247.0	0.370
								1985.4895	247.0	0.370
10598	STF 2173	158614	17303-0103	6.0	6.1	G9IV-V	G9IV-V	1985.4869	157.4	0.923
								1985.4871	157.3	0.920
12961	A 1658	187283	19487+1503	8.2	8.5	F5V	F6V	1985.4928	212.3	0.204
								1985.8341	209.5	0.196
15215	STT 448	206373	21410+2921	8.4	9.4	G0		1985.4983	199.5	0.429
								1985.8480	198.5	0.423

late the range of orbit sizes that are detectable by the speckle technique. According to Kepler's law, this translates into a range of detectable orbital periods. This range covers only a portion of the total period distribution for binary stars. Our task here is to evaluate the fraction of stars in the total distribution that are expected to be in the detectable portion of the period distribution.

These two selection effects are best analyzed together. Because the range of binary periods that can be detected by the speckle technique is a function of distance, consider concentric shells in space, each with a thickness corresponding to a distance modulus difference of $\Delta(V - M_v) = 1.0$. Shell A includes all observed stars with distance moduli between 5 and 6, shell B between 4 and 5, and so on, as shown in Table IV. Next, since main-sequence stars of different spectral types have different absolute magnitudes, let us divide the sample into three groups according to spectral class, i.e., F, G, and K. To each group, we assign an average M_v, i.e., $M_v(\mathrm{F}) = 4.0$, $M_v(\mathrm{G}) = 5.0$, and $M_v(\mathrm{K}) = 6.0$. Let us consider next the distribution of each spectral-class group as a function of distance. Table IV lists the number of stars observed and of identified binaries in each space shell for each spectral class. Also listed are the ranges in physical separations and orbital periods in the observable window, set by the range of angular resolution detected by the speckle photometer.

We see that there is complete overlap of all three spectral-class groups for shells C, D, and E and will therefore consider here these three shells only. We note that in C, D, and E, which together cover a range of detectable periods from 0.9 to 258 yr, the frequency of observed binaries is, within the uncertainties, nearly uniform and averages to about 8%. This is consistent with the nearly flat distribution derived by Abt (1979, Fig. 6) for disk binaries in the same period range. Using Abt's period distribution function, we find that the period range detectable in our survey includes somewhere between 30% and 50% of the total number of physical pairs in the volume of space surveyed. If we could detect all binaries in this period range, our observed frequency of 8% would then translate into a total binary frequency in the range of 16%–28%. The total binary frequency may in fact be much larger than that, however, because a third selection effect must also be taken into account.

(3) The third restriction on our search is that $\Delta m < 2.5$ mag. If $L \propto \mathscr{M}^5$, and the primary and secondary masses are $\mathscr{M}1$ and $\mathscr{M}2$, respectively, we must then have $\mathscr{M}2 > 0.5\mathscr{M}1$. In order to evaluate the importance of this effect, we need to know the likely distribution of mass ratios among the binaries in our sample. Abt (1979) has reviewed this topic and has pointed out that binary systems can be divided into two groups according to their orbital period: bifurcation doubles, whose frequency is proportional to $\mathscr{M}2^{0.4}$, and the independent-condensation doubles, which follow a van Rhijn distribution peaked toward low masses for $\mathscr{M}2$. Since the binaries in our sample have periods much longer than the transition period from one group to another (which is 100 days or less), we expect that the van Rhijn distribution (shown in Fig. 1 in Abt 1979) may apply, particularly in view of Partridge's (1979) conclusion that the frequency of long-period binaries is the same for high- and low-velocity stars. In this case, and using $\mathscr{M}2 > 0.5\mathscr{M}1$, Abt's Fig. 1 suggests that, for each pair that we have observed, there could be between two and five times (depending on the spectral types of the primary) as many secondaries that are too faint to be detected because their masses are below $0.5\mathscr{M}1$. This correction factor should then be applied to the frequencies derived in the previous paragraph, and could lead to a very high total frequency of binaries for halo stars.

In summary, taking into account the large uncertainties due to the small size of our sample, and correcting for the selection effects introduced by our survey technique, we conclude that our data are compatible with the conclusion that the total frequency of long-period pairs among high-velocity stars is very high, and may not differ from that observed for low-velocity stars.

b) Speckle Binaries

The angular resolution of speckle interferometry when carried out at the 4 m telescope allows the detection of halo-population binary stars that would generally not be seen by visual double star or variable radial-velocity surveys. Visual double star surveys detect generally large separations and longer periods; they therefore do not supply the needed orbital elements and the mass–luminosity function in a reasonable length of time. The resolution of spectroscopic binaries using radial-velocity observations, on the other hand, leads to the detection of short periods and small semimajor axes. Thus speckle interferometry can provide important data in

TABLE III. Negative results.

Name	HD/BD Number	α, δ (2000)	Spectral Classif.	V Mag.	Epoch
-03 5751	224959	00021-0250	R0	9.9	85.4985
+85 0412	245	00085+8647	G2 V	9.2	85.4985
					85.8402
+26 0043	1795	00224+2700	VAR	8.2	85.8401
+49 0073	------	00251+5006	dK3	8.6	85.4985
+74 0014	2520	00300+7515	dK0	8.2	85.4985
					85.8402
G 242-65	+71 0031	00437+7211	sdA9	10.23	85.8402
+39 0167	4174	00446+4041	M2e	7.4	85.4985
					85.8401
+29 0141	4744	00499+3027	G5 IV	7.6	85.4985
					85.8403
+62 0161	4842	00514+6255	M6	9.1V	85.4985
					85.8402
RV Cas	5016	00526+4725	M6e	7.6-15	85.4985
+23 0123	5223	00542+2404	R3	8.8	85.8403
HR 321	6582	01079+5457	G5Vp	5.17	85.4985
					85.8456
+01 0212	6734	01080+0200	K0 IV	6.7	85.8403
G 243-63	6755	01096+6133	G0 V	7.73	85.8402
+57 0227	236672	01146+5755	B6	9.0	85.8430
+47 0485	10465	01432+4831	MA	7.0	85.8430
G 245-32	+72 0094	01472+7328	sdG3	9.92	85.8430
+50 2360	232534	01485+5107	B3	9.5	85.8430
-19 0369	12655	02036-1837	B9 V	8.3	85.8375
+51 0527	13738	02155+5231	K4	7.2	85.8431
+57 0525	13716	02157+5746	B1 IV	8.5	85.8431
+24 0330	13913	02161+2503	MD	7.3V	85.8375
+57 0570	15024	02274+5751	G5 V	9.7	85.8376
+61 0416	15069	02283+6213	G1 V	7.9	85.8377
+59 0515	15862	02355+5948	G5 V	8.93	85.8377
G 73-67	+04 0415	02346+0527	K3 V	9.78	85.8376
+57 0608	236982	02408+5829	K0	9.8	85.8376
+60 0585	------	02533+6051	K5 V	9.5	85.8377
+59 0562	237019	02535+6028	O7 V	9.0	85.8377
+01 0509	18012	02536+0158	G8 V	6.6	85.8404
+00 0495	18682	03003+0058	K0	8.4	85.8403
+05 0435	18702	03006+0559	K0 V	8.2	85.8404
+27 0478	19165	03058+2741	G0 V	8.6	85.8378
G 37-26	19445	03084+2621	G5 VI	8.06	85.8378
-14 0646	20622	03187-1415	K0 IV	7.9	85.8432
+59 0639	20688	03228+6002	G5 V	8.6	85.8431
X 4974	------	03257-0815	K3 V	8.5	85.8403
G 246-38	+66 0268	03312+6644	sdF5	9.91	85.8377
+35 0701	21567	03301+3540	VAR	7.9V	85.8377
-03 0592	22879	03403-0313	F8 V	6.7	85.8487
+51 0798	24341	03548+5225	G1 V	7.9	85.8433
-23 1619	24616	03540-2308	dG0	6.8	85.8432
+22 0626	25532	04042+2325	F6 V	8.2	85.8406
-16 0793	26298	04091-1624	F2 V	8.1	85.8405
+47 0977	------	04214+4820	K8	9.1	85.8514
+31 0769	281989	04232+3212	F8	8.8	85.8378
+06 0676	27821	04238+0623	A7 V	8.6	85.8488
+24 0659	283668	04279+2427	K3V(F0)	9.42	85.8378
+43 1029	------	04392+4417	K0 V	9.2	85.8380
+41 0931	29587	04416+4207	G2 V	7.2	85.8380
+34 0911	30443	04493+3500	R8	9.0	85.8380
+00 0916	32023	05003+0100	F8 V	9.1	85.8435
+31 0846	282707	05018+3138	G0	8.9	85.8380
+15 0726	------	05027+1520	N6	9.4	85.8488
+55 0960	237354	05085+5526	G2 V	9.3	85.8542
+39 1248	34411	05191+4007	G0 V	4.7	85.8516
+28 0965	40440	06000+2845	F5 V	8.8	85.8381
+27 0962	250684	06031+2726	B8 V	9.7	85.8380
+19 1185	250792	06032+1922	G0 V	9.0	85.8380
+26 1067	251383	06059+2634	K2 V	9.44	85.8380
-12 1470	44996	06243-1258	B5 Ve	6.1	85.8381
+10 1301	50060	06519+1048	F9 V	7.8	85.8382

TABLE III. (continued)

Name	HD/BD Number	α,δ (2000)	Spectral Classif.	V Mag.	Epoch
-10 1774	51480	06572-1049	B5p	6.9	85.8382
-08 1641	51478	06572-0904	VAR	8.4V	85.8382
-04 1806	53452	07050-0433	B3	9.0	85.8408
+47 1419	55575	07158+4715	G0 V	5.5	85.8409
-01 1677	57678	07222-0152	K0	8.8	85.8545
+11 1592	59180	07292+1135	K0	7.0	85.8436
+19 1749	59374	07305+1858	F8 V	8.5	85.8491
+25 1709	60298	07348+2458	G2 V	8.0	85.8491
+31 1684	64090	07535+3038	G0 VI	8.28	85.8409
+33 1694	------	08252+3237	dK6	9.2	85.8409
+75 0512	119227	13387+7419	M4	7.7V	85.4977
+77 0521	------	13445+7714		9.4	85.4977
+25 2782	126991	14283+2431	G2 V	8.2	85.4895
+72 0674	135694	15115+7150	dK0	8.9	85.4894
+40 2903	139323	15360+3950	K3 V	7.8	85.4895
-10 4149	140283	15431-1056	F3 VI	7.24	85.4924
+40 2929	141826	15495+3934	NB	6.9V	85.4894
+28 2503	143291	15586+2744	K0 V	8.0	85.4895
+47 2291	144205	16027+4714	M6e	5.8V	85.4894
+67 0950	149880	16327+6645	VAR	6.4	85.4870
+25 3115	150580	16410+2452	K2	6.0	85.4870
-19 4431	151504	16485-1917	G5	8.4	85.4870
+62 1520	153344	16548+6206	G5 IV	7.08	85.4870
+25 3182	154049	17020+2502	K2	7.9	85.4870
+59 1783	154712	17033+5935	K4 V	8.6	85.4870
-07 4427	156802	17200-0801	G2 V	8.0	85.4870
+01 3421	157089	17211+0126	G0 V	7.0	85.4871
					85.4922
+32 2896	157214	17206+3229	G2 V	5.3	85.4870
+06 3412	157809	17253+0606	sF9	7.0	85.4871
+31 3025	------	17267+3104	G7 V	9.1	85.4870
+31 3027	158226	17267+3105	G0 V	8.1	85.4870
ADS 10598	158614	17304-0104	G9IV-V	5.31	85.4870
+06 3455	159482	17347+0601	G0 V	8.5	85.4924
G 170-56	+18 3423	17383+1834	F6 V	9.78	85.4925
G 20-8	+02 3375	17398+0225	sdF5	9.98	85.4924
+25 3344	161817	17467+2545	A2 V	6.9	85.4925
-09 4604	161770	17478-0936	sdG	9.6	85.4924
+04 3509	161848	17477+0457	K1 V	8.5	85.4924
-07 4517	162756	17530-0755	G0 V	7.6	85.4924
A 10937 B	------	17565+5813		10.0	85.4925
-13 4807	163810	17587-1305	sdF8	9.63	85.4924
+04 3589	165401	18056+0440	G2 V	6.8	85.4980
+30 3137	166382	18091+3101	MD	6.9	85.4925
+30 3142	166601	18100+3050	F5 V	8.1	85.4980
+36 3066	167740	18149+3640	MD	8.8	85.4925
					85.8423
+45 2684	168009	18155+4513	G2 V	6.3	85.4925
					85.8423
+03 3656	167766	18166+0342	MD	8.7	85.4927
TX Lyr	------	18180+0407	M2e	10.4-13	85.4927
+45 2716	170357	18267+4605	G1 V	8.3	85.4925
+43 3030	------	18370+4357		9.5	85.4925
-06 4859	173093	18439-0649	F7 V	6.3	85.4927
-00 3555	173883	18477-0014	G0 V	8.4	85.4981
					85.8424
+23 3477	174623	18504+2406	K5	7.1	85.4927
-05 4811	175518	18559-0544	G5 V-IV	8.2	85.4927
+17 3842	177459	19042+1733	F5	6.6	85.4927
-08 4836	177399	19048-0839	K0	7.5	85.4927
+25 3719	177830	19053+2555	K2	7.6	85.4927
					85.8424
+25 3780	181047	19179+2522	K5	8.8	85.4927
					85.8533
G 125-4	+41 3306	19190+4139	K0 V	8.86	85.8424
+10 3873	181882	19219+1055	K2	7.3	85.4927
HR 7373	182572	19249+1156	G8IV	5.16	85.4928
+42 3338	182989	19255+4247	F5(V)	6.9	85.4927
+19 4026	231475	19274+1953	K0	9.1	85.4927
+26 3578	338529	19325+2624	sdF4	9.36	85.4927
+56 2257	239124	19325+5623	A2-IV	9.1	85.4928
					85.8533
+32 3474	184499	19335+3312	G0 V	6.63	85.4927

TABLE III. (continued)

Name	HD/BD Number	α,δ (2000)	Spectral Classif.	V Mag.	Epoch
					85.8424
AGK+212007	+21 3829	19344+2143	B8 V	9.3	85.4928
ADS 12664	184860	19368-1026	K2V,K5	8.23	85.4928
+85 0332	187216	19243+8522	R3	9.2	85.4982
+48 2922	185657	19379+4917	G6 V	6.3	85.4928
					85.8370
+48 2942	186686	19436+4847	M3	6.4	85.4928
					85.8370
+38 3801	188326	19530+3846	G8 IV	8.0	85.4928
					85.8370
+30 3806	188669	19551+3041	K0 V	7.1	85.4928
+34 3846	227196	20021+3428	K5	8.9	85.4982
+28 3639	191445	20090+2841	K5 V	9.2	85.8371
AGK+302052	+30 3915	20091+3033	A1 V	9.5	85.4929
+25 4124	191615	20100+2532	K0 IV	8.0	85.4928
+64 1427	193030	20142+6446	G5 IV	7.2	85.4929
+05 4481	------	20219+0611	G V-VI	10.1	85.4930
G 186-26	------	20248+2503	sdF8	10.82	85.8534
+09 4529	194598	20262+0927	F5 V	8.36	85.4930
					85.8479
+18 4505	195019	20283+1846	G5 V	6.9	85.4930
+01 4304	195275	20303+0153	M5e	9.2	85.4930
					85.8479
+36 4095	195407	20298+3659	B5 V	7.7	85.4929
					85.8479
-09 5491	195636	20328-0922	G8?	9.54	85.4930
+39 4260	196790	20382+3933	G0e	7.9	85.4929
-00 4084	197623	20449+0018	dG5	7.4	85.4930
C 2711	+74 0891	20524+7435	dG5	7.81	85.8534
+06 4741	200779	21053+0705	K5 V	8.9	85.4930
					85.8396
-06 5683	201099	21077-0534	G0	7.6	85.4982
+28 3996	201346	21082+2837	K0 IV	8.4	85.8398
+26 4091	201626	21100+2637	K2	8.0	85.8398
+23 4264	201889	21120+2410	F8 V	7.9	85.8398
+14 4556	202017	21129+1535	dF8	8.4	85.4982
X Peg	------	21208+1427	M2e	9.0-14	85.4983
+15 4404	203631	21231+1630	K5	7.5	85.4983
					85.8480
-13 5945	204587	21300-1230	M0 V	9.3	85.4983
					85.8535
+18 4947	210483	22104+1848	G0 V	7.9	85.4983
					85.8371
+25 4691	210925	22132+2557	G5 V	6.8	85.4982
					85.8372
+54 2745	235807	22212+5533	B1 IV	9.4	85.8399
+39 4851	213191	22290+4019	VAR	7.6	85.4983
					85.8425
+56 2818	214419	22369+5654	OB/WN	8.9	85.4983
					85.8398
BH Peg	------	22529+1547		10-10.7	85.4984
+49 3965	216534	22530+4952	B4 V	8.0	85.4983
+29 4940	221170	23295+3026	K2 V/IV	7.68	85.4984
					85.8426
+30 4982	221830	23354+3101	G0 V	6.7	85.4984
					85.8426
+57 2787	222794	23434+5804	G2 V	7.0	85.8537
-08 6177	222766	23461-0739	dG4	9.7	85.4985
					85.8427
+01 4774	------	23492+0225	M2	8.9	85.4984
					85.8427
M 74	------	23525+6252	G0 V	9.5	85.4984
					85.8428
+58 2676	224424	23578+5943	B0	7.8	85.4984
					85.8428

TABLE IV. Calculated binary frequency.

Shell	Number of stars: Observed F	G	K	Binaries found F	G	K	d (pc)	a(min) (AU)	P(min) (yr)	a(max) (AU)	P(max) (yr)
A	6	—	—	1	—	—	129	4.6	6.9	129	1029
B	8	10	—	1	0	—	82	2.9	3.5	82	527
C	4	16	9	0	2	1	51	1.8	1.8	51	258
D	4	15	18	1	1	0	32	1.2	0.9	32	128
E	0	8	12	0	1	1	20	0.8	0.5	20	63
Binaries in shell									C	3/29	
									D	2/37	
									E	2/20	
									Total	7/86	= 8%

the regime where visual and spectroscopic detection of binary stars is less effective.

All of the newly resolved and a majority of the previously known binaries in this survey fall into an orbital-period regime not generally detectable by spectroscopic and visual methods. They would, therefore, not be discovered without the application of speckle interferometry. This selection effect has also been pointed out in Paper I in connection with bright stars. An extension of our survey to magnitudes fainter than 10.5 would increase the number of newly detected halo binaries. However, since those fainter stars would be, on the average, more distant than the brighter ones, we would be finding binaries with increasingly longer periods. Since we are interested in determining masses in a reasonable length of time, the extension to fainter magnitudes is not very productive.

The distributions in spectral type and visual magnitude are shown in Figs. 1 and 2, respectively, for all stars observed, and also for the binary candidates found in this survey (dark area). Using this limited data, the peaks of the distributions in both figures suggest a similar distribution between the observing list and the binary system found in the sample.

Distances were estimated for the stars listed in Tables I and II using their spectral types and visual magnitudes. Absolute magnitudes were obtained from the MK spectral types according to Keenan's calibration (Keenan 1963). Among these ten binaries, only four stars have trigonometric parallaxes listed in the new edition of the *Yale General Parallax Catalog* (YPC, van Altena 1987). A comparison of the trigonometric and spectroscopic parallaxes for these four stars shows excellent agreement. Of the ten stars, all are within 100 pc of the Sun and eight systems have linear separations < 20 AU. Using the mass–luminosity relation given by McAlister and Hartkopf (1984), and assuming circular orbits, four stars are found to have periods less than 20 yr (Table V).

These halo binary candidates will be monitored in the future for additional confirmation and to determine their orbital elements using the GSU/CHARA speckle camera.

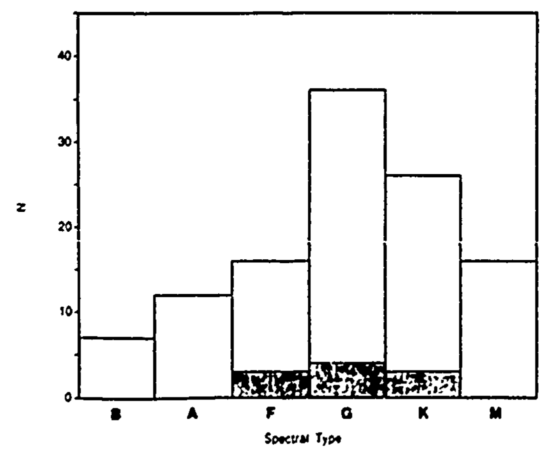

FIG. 1. Distribution in spectral type for all stars observed (light area) and binary candidates found (dark area).

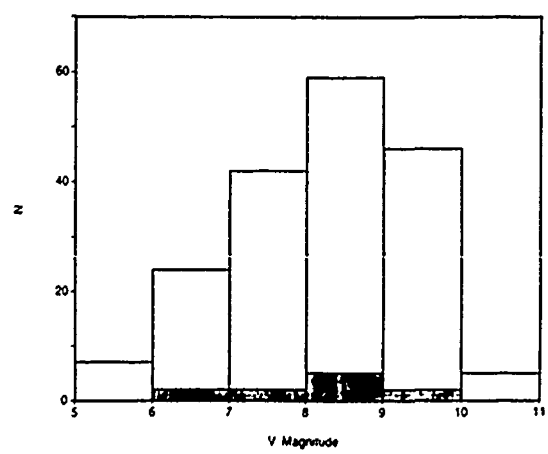

FIG. 2. Magnitude distribution for all stars observed (light area) and binary candidates found (dark area).

TABLE V. Estimated mass, distance, linear separation, and period for the halo binaries.

HD	ρ	R.v. (km/s)	V	Spt.	M_v	Mass	π	d (pc)	a (AU)	P (yr)
21794	0.099	− 71	6.36	F7 V	3.9	1.2		30	3.4	4.0
49409	1.088	− 83	8.4	G0 V	4.4	1.0	0".017	59	64.2	363.7
130669	0.150	− 91	9.2	K2 V	6.3	0.7		38	5.7	11.5
139341	0.370	− 71	7.5	K2 V	6.3	0.7	0".048	21	7.8	18.4
158614	0.923	− 80	6.0	G9 V–IV	5.7	0.8	0".052	19	17.5	57.9
187283	0.204	− 65	8.2	F5 V,F6 V	3.4	1.3		91	18.6	49.7
189711	0.221	− 168	8.43	N0 V	9.2[b]	0.4		32	7.1	21.2
+ 174708[a]	0.205	− 295	9.48	F6 VI	4.7[c]	1.2	0".016	63	12.8	29.6
206373	0.429	− 91	8.4	G0 V	4.4	1.0		63	27.0	99.2
222794	0.057	− 71	7.1	G0 V	4.7	1.0		35	2.0	2.0

[a] + 17°4708 = G126-62.
[b] Set M0 V for N0 V (Jaschek 1985).
[c] Absolute magnitude for F6 VI set = F6 V(3.7) + 1.0 (Sandage 1970).

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GAMMA PERSEI—NOT OVERMASSIVE BUT OVERLUMINOUS

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ABSTRACT

Measurement and analysis of the set of Michigan spectrograms of the 14ʸ6 binary γ Per shows that the masses of the A3 and G8 III stars are $2.0\mathscr{M}_{\odot}$ and $3.0\mathscr{M}_{\odot}$ rather than the abnormally large values for the types found by McLaughlin, 2.8 and 4.9. The decreases are primarily due to an upward revision of the large orbital eccentricity. Speckle interferometric observations of high quality covering nine years with the components resolved are analyzed. Agreement of the elements in common between interferometric and spectrographic orbits is excellent. The orbit is seen nearly edge-on. The well-determined parallax, 0″014, obtained by combining linear and angular sizes of the relative orbit, along with Bahng's evaluation of the magnitude difference between the components, leads to absolute magnitudes M_V of $+0.3$ and -1.1 for the A star and G giant, respectively, values more than a magnitude more luminous than "standard" values for the spectral types. Thus, each star appears to be in a state of rapid evolution, a situation not permitted by evolutionary theory for stars of such different mass if they have a common origin.

I. INTRODUCTION

Gamma Persei has long been known to have a variable radial velocity and composite spectrum. The only available analysis of radial velocities is that published in abstract form by McLaughlin (1948) on the basis of prismatic spectrograms obtained at Michigan. The period is 14.6 yr. Each of McLaughlin's minimum masses, $4.9\mathscr{M}_{\odot}$ for the G8 giant and $2.8\mathscr{M}_{\odot}$ for the early A star, is considerably larger than any other well-determined mass for a star of the spectral type (e.g., Popper 1980). McAlister (1982) has analyzed the astrometric observations of γ Per, primarily his own speckle results, available in 1981. He concluded that not only are the masses larger than expected for the types, but so are the luminosities.

In the present contribution, we discuss the Michigan spectrograms anew as well as the astrometric observations now available in order to derive nearly definitive properties of the system.

II. SPECTROGRAPHIC ORBITS

The velocities of the 34 spectrograms employed by McLaughlin (1948) in his analysis of the orbits of γ Per have not been published. Through the good offices of A. P. Cowley and W. A. Hiltner, one of us was able to obtain the Michigan collection of one hundred measurable prismatic spectrograms obtained between 1937 and 1951 plus one critical observation in 1932. The plates from 1932 to March 1941 and from August 1943 to March 1949 form a homogeneous one-prism set (78 plates) having a scale of 26.4 Å mm^{-1} at the Ca II K line and 31.9 Å mm^{-1} at Hδ. The two other groups of plates have slightly higher dispersions from a two-prism configuration. All the plates have been measured with a Grant Instrument Co. oscilloscopic scanning device in both directions. There are numerous sharp lines from the cool component, but, as noted by McLaughlin, only the Ca II K line of the hotter star is measurable. This line is so much sharper than the K line of the cooler star that there is no confusion between the two. On all well-exposed plates, the K line of the A star appears sharp and symmetrical. It appears unlikely that the 0.6 Å displacement between the centers of the K lines of the components near periastron can cause a systematic effect in the position of this sole line of the A star that is employed for its velocities. The Ca II H line of the A star is not resolved from the broad Hϵ line. All the hydrogen lines of the A star are so chopped up by sharp lines of the cooler star as to be unmeasurable. The appearance of the spectrum near the K line is shown in Fig. 1.

Velocities of the cool star (V_c) are based on lines in the wavelength range $\lambda\lambda$ 3888–4167 Å. Most of the spectrograms are weak at shorter wavelengths, and the dispersion decreases markedly at longer wavelengths. Furthermore, this range includes the Ca II K line, so that possible systematic effects in the velocities of the components are minimized. Twenty lines of the cool star were found to give consistent velocity variation. Their wavelengths were taken from the solar list (Moore *et al.* 1966) and were adjusted for systematic differences in velocity. The average internal standard deviation of a velocity of the cool star is 1.0 km s^{-1}. Some of the lines are indicated in Fig. 1.

The velocities are listed in Table I. The quantities V_h are the K line measures for the A star, V_c the G star velocities. A somewhat uncertain curvature correction of -1.0 km s^{-1} has been applied.

In Table I, dates with only one decimal given are for observations with the time of exposure not readily available. Because of the long period, the uncertainty of 0.1 day is unimportant. The phases are fractions of the period after periastron in the adopted orbital solution, to which the residuals in the table also relate. In carrying out the solutions (Table II), it is found that the velocities from the 22 two-prism plates are systematically more positive than those from the 78 one-prism plates. The differences for the two components and for the two epochs (1941–1943 and 1949–1951) average 2.5

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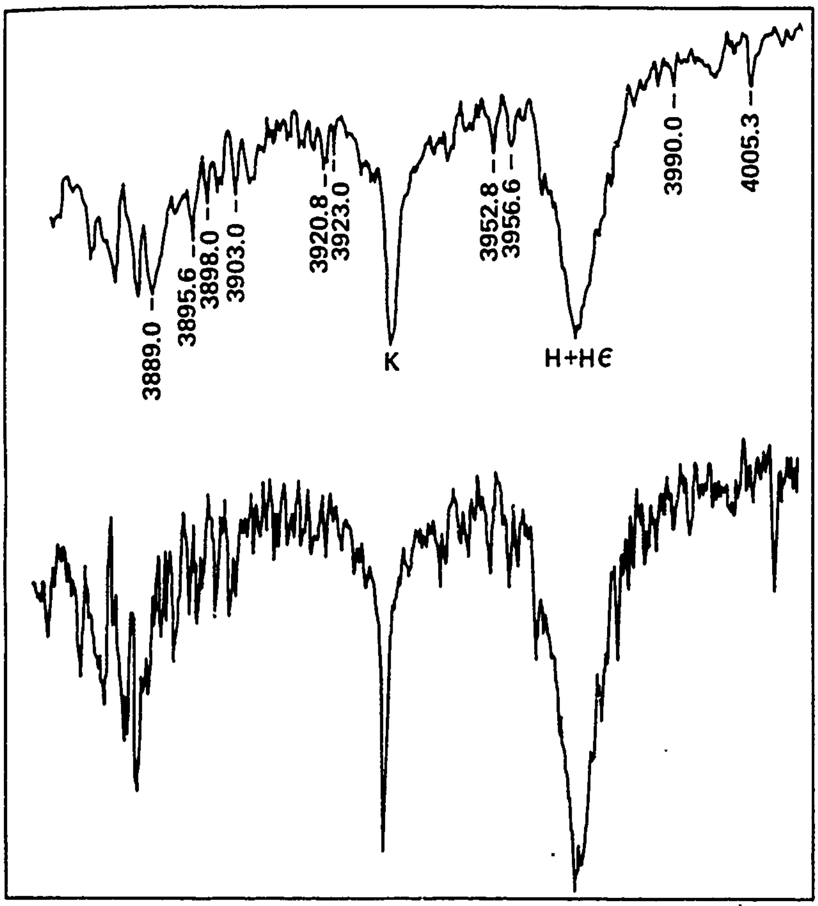

FIG. 1. Microdensitometer tracings of spectrograms of γ Per in the vicinity of the Ca II K line. Above: a Michigan prismatic spectrogram, employed in this investigation; original scale 26.4 Å mm^{-1} at K. Lines marked are used for radial velocities except for H + Hϵ. Below: a Lick grating spectrogram, original scale 10.9 Å mm^{-1}. The core of the relatively sharp K line of the A star appears uninfluenced by the broad K line of the G giant.

TABLE I. Radial velocities of γ Per.

JD-2400000	Phase	V_c	O-C	V_h	O-C
26996.76	0.00837	-19.7	- 1.4	-35.8	- 2.3
28823.23	0.35002	- 6.1	- 2.4	1.0	- 3.1
28868.73	0.35854	- 4.4	- 0.6	4.0	- 0.2
29109.89	0.40365	- 5.6	- 1.6	4.8	+ 0.3
29119.90	0.40552	- 5.8	- 1.8	2.5	- 2.0
29140.80	0.40943	- 7.8	- 3.8	2.1	- 2.5
29170.82	0.41504	- 5.0	- 1.0	5.6	+ 1.0
29198.80	0.42028	- 4.1	0.0	6.6	+ 2.0
29223.54	0.42490	- 4.6	- 0.5	8.4	+ 3.7
29313.65	0.44176	- 0.1	+ 4.0	8.2	+ 3.4
29455.89	0.46837	- 3.0	+ 1.2	8.4	+ 3.5
29479.89	0.47286	- 3.9	+ 0.3	7.5	+ 2.6
29514.74	0.47938	- 5.2	- 0.9	5.6	+ 0.7
29548.71	0.48573	- 3.8	+ 0.5	4.0	- 1.0
29578.71	0.49134	- 5.6	- 1.3	2.0	- 3.0
29609.70	0.49714	- 3.4	+ 0.9	5.2	+ 0.2
29637.69	0.50237	- 4.2	+ 0.1	7.0	+ 2.0
29675.54	0.50945	- 2.8	+ 1.5	5.6	+ 0.6
29936.66	0.55830	- 5.7	- 1.3	5.8	+ 0.6
29954.59	0.56165	- 6.2	- 1.8	3.0	- 2.2

TABLE I. (continued)

JD-2400000	Phase	V_c	O-C	V_h	O-C
29978.67	0.56616	- 5.3	- 0.9	4.7	- 0.5
30023.70	0.57458	- 3.7	+ 0.7	8.2	+ 3.0
30058.54	0.58110	- 4.4	0.0	6.0	+ 0.8
[a]30286.67	0.62379	- 4.3	+ 0.2	7.0	+ 1.8
[a]30317.6	0.62956	- 4.2	+ 0.3	8.4	+ 3.2
[a]30373.60	0.64003	1.8	+ 6.3	9.2	- 4.0
[a]30379.53	0.64114	- 0.9	+ 3.6	8.4	+ 3.2
[a]30404.64	0.64584	0.4	+ 4.9	9.9	+ 4.7
[a]30438.54	0.65218	0.3	+ 4.8	----	----
[a]30592.91	0.68105	- 1.1	+ 3.3	9.2	+ 4.0
[a]30602.85	0.68291	- 4.8	- 0.4	7.3	+ 2.1
[a]30652.74	0.69224	- 3.8	+ 0.6	4.4	- 0.8
[a]30730.65	0.70682	0.0	+ 4.4	9.1	+ 4.0
[a]30753.56	0.71110	0.4	+ 4.8	12.5	+ 7.4
[a]30778.57	0.71578	- 2.7	+ 1.7	3.4	- 1.7
[a]30807.57	0.72121	- 3.3	+ 1.0	5.3	+ 0.2
30964.80	0.75062	- 2.1	+ 2.1	3.4	- 1.5
30985.79	0.75454	- 5.5	- 1.3	3.3	- 1.6
31006.72	0.75846	- 3.4	+ 0.8	1.5	- 3.4
31057.67	0.76799	- 5.4	- 1.2	3.2	- 1.6
31107.56	0.77732	- 5.2	- 1.1	3.4	- 1.3
31342.89	0.82134	- 2.0	+ 1.8	----	----
31770.68	0.90136	- 1.8	+ 0.3	2.6	+ 0.9
31834.56	0.91331	- 2.0	- 0.4	- 1.0	- 1.9
31887.54	0.92322	- 3.7	- 2.6	- 2.1	- 2.2
31907.60	0.92697	- 1.9	- 1.1	- 1.6	- 1.3
32013.88	0.94685	2.8	+ 1.8	- 2.5	+ 0.6
32027.87	0.94947	- 0.2	- 1.6	- 1.6	+ 2.0
32039.87	0.95172	3.5	+ 1.8	- 3.6	+ 0.5
32046.79	0.95301	4.2	+ 2.3	- 2.4	+ 2.0
32119.68	0.96664	7.8	+ 3.1	- 3.6	+ 5.1
32168.68	0.97581	9.8	+ 1.9	----	----
32236.65	0.98852	17.8	+ 2.0	- 24.4	+ 1.0
32243.54	0.98981	17.4	+ 0.6	- 27.5	- 0.6
32243.56	0.98982	18.4	+ 1.6	- 28.3	- 1.4
32245.56	0.99019	19.6	+ 2.5	- 25.3	+ 2.1
32249.57	0.99094	20.2	+ 2.5	- 25.0	+ 3.4
32256.55	0.99225	16.3	- 2.5	- 25.8	+ 4.2
32271.55	0.99505	21.7	+ 0.7	- 33.6	- 0.3
32272.58	0.99525	20.3	- 0.8	- 29.8	+ 3.7
32279.56	0.99655	22.8	+ 0.8	- 38.6	- 3.8
32290.56	0.99861	23.8	+ 0.8	- 39.0	- 2.7
32370.88	0 01363	18.1	- 0.4	- 25.7	+ 2.7
32371.89	0.01382	18.7	+ 1.1	- 31.0	- 2.8
32378.89	0.01513	18.2	+ 1.4	- 24.4	+ 2.6
32386.86	0.01662	15.2	- 0.7	- 26.6	- 1.0
32391.84	0.01755	14.1	- 1.3	- 23.8	+ 1.0
32392.91	0.01775	14.5	- 0.8	- 25.0	- 0.4
32398.86	0.01887	15.5	+ 0.8	- 23.8	- 0.1
32400.90	0.01925	11.4	- 3.0	- 22.2	- 0.8

TABLE I. (continued)

JD-2400000	Phase	V_c	O-C	V_h	O-C
32406.89	0.02037	14.4	+ 0.5	- 26.4	- 3.9
32407.82	0.02054	15.7	+ 1.9	- 17.8	+ 4.6
32410.85	0.02111	11.8	- 1.7	- 24.6	- 2.7
32445.75	0.02764	9.5	- 1,2	- 16.2	- 1.5
32446.71	0.02782	10.8	+ 0.2	- 17.4	+ 0.2
32452.71	0.02894	11.7	+ 1.5	- 18.6	- 1.6
32458.73	0.03007	9.0	- 0.8	- 18.2	- 1.8
32465.8	0.03138	9.5	+ 0.1	- 14.6	+ 1.1
32473.8	0.03288	8.6	- 0.3	- 13.8	+ 1.2
32483.73	0.03474	9.3	+ 0.9	- 15.0	- 0.8
32501.7	0.03809	8.0	+ 0.5	- 13.8	- 0.9
32529.7	0.04334	5.2	- 1.1	- 14.5	- 3.4
32541.7	0.04559	5.7	- 0.2	- 11.5	- 1.0
32573.7	0.05156	3.7	- 1.2	- 10.0	- 1.1
32601.6	0.05679	3.9	- 0.2	- 7.2	+ 0.6
32839.8	0.10134	1.6	+ 1.1	- 1.0	+ 1.3
32846.8	0.10265	0.6	+ 0.1	- 4.4	- 2.2
32867.8	0.10657	2.6	+ 2.3	- 1.3	+ 0.6
32908.8	0.11424	0.5	+ 0.6	1.0	+ 2.4
32956.6	0.12319	2.2	+ 2.6	- 2.2	- 1.3
[a]33229.7	0.17427	1.0	+ 2.8	4.2	+ 3.0
[a]33255.7	0.17914	0.0	+ 1.9	3.0	+ 1.7
[a]33370.5	0.20062	1.6	+ 3.9	7.2	+ 5.3
[a]33554.7	0.23507	- 0.6	+ 2.2	8.4	+ 5.8
[a]33603.71	0.24424	- 1.9	+ 1.0	4.6	+ 1.8
[a]33631.70	0.24948	- 2.3	+ 0.6	2.4	- 0.5
[a]33700.58	0.26236	- 2.2	+ 0.8	5.6	+ 0.5
[a]33730.55	0.26797	- 1.7	+ 1.4	4.8	+ 1.6
[a]33948.74	0.30878	- 4.4	- 1.0	3.0	- 0.7

[a]Two-prism spectrograph; otherwise one prism. Similar dispersions. Two-prism velocities omitted in most solutions. See text and Table 2.

km s^{-1}. The two-prism velocities have been omitted except for solution (2), in which the differences $V_c - V_h$ are employed.

With the exception of the first spectrogram, obtained in 1932, the Michigan observations cover less than one orbital cycle of 14.6 yr. The 1932 observation, obtained near the time of maximum velocity separation of the components, is a crucial one. Determination of the orbital period depends heavily upon this single plate, obtained one cycle earlier than the numerous plates from 1947, when the stars passed rapidly through periastron, close to the nodal epoch (ω being near zero). It has not been possible to determine clearly whether the 1932 observation was obtained before or after periastron passage. Thus, there is an ambiguity in the period. This uncertainty is less than 100 days, or 2%, since the 1932 plate was, fortunately, obtained close to maximum orbital velocity. The early velocities of the cool giant (Lord 1905; Küstner 1908; Campbell and Moore 1928) do not cover sufficient ranges of velocity to be helpful in resolving the ambiguity in period.

In each of the solutions for the orbital elements in Table II, the two values of the period are listed. The differences in the values of the other elements, as dependent on the choice of period, are in all cases much less than the mean errors of the elements, and average values are listed. Since the period is so strongly dependent on the one observation, the statistical uncertainty of the period is not properly evaluated in the least-squares analysis. Additional solutions have been carried out in which the velocities of the 1932 plate are changed by one standard deviation (1.5 km s^{-1} for V_c, 2.2 km s^{-1} for V_h). The effect on the period is 14 days, and this value is listed in Table II for the uncertainty in the period. The effects

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TABLE II. Solutions to the spectroscopic orbit.

Solution	(1) V_c	(1) V_h	(2) $V_c - V_h$	(3) V_c	(3) V_h	(4) V_h	(5) V_h	(6) V_c	(6) V_h	(7) V_c	(7) V_h
$^aP_1$(days)	5352.5 ± 14	5341.4 ± 14	5345.1 ± 14	5345.1 ---	5345.1 ---	5352.5 ---	5352.5 ---	5346 ± 16	5346 ± 16	5350 ---	--- ---
$^aP_2$(days)	5258.8 ± 14	5286.4 ± 14	5277.8 ± 14	5277.8 ---	5277.8 ---	5258.8 ---	5258.8 ---	5277 ± 25	5277 ± 25		
^bT(JD-2430000)	2291.0 ± 5.8	2301.3 ± 4.3	2298.5 ± 2.7	2298.5 ---	2298.5 ---	2291.0 ---	2291.0 ---	2298 ± 8	2298 ± 8	2263 ---	--- ---
e	0.789 ± 0.010	0.817 ± 0.010	0.805 ± 0.006	0.805 ---	0.805 ---	0.789 ---	0.789 ---	0.804 ± 0.02	0.804 ± 0.02	0.72 ---	--- ---
ω(°)	351.8 ± 2.0	170.7 ± 1.9	351.5 ± 1.1	351.5 ---	171.5 ---	171.8 ---	171.8 ---	351.5 ± 1.5	171.5 ± 1.5	344 ---	--- ---
K(km s^{-1})	13.8 ± 0.4	22.0 ± 0.7	35.6 ± 0.7	14.3 ± 0.3	21.3 ± 0.4	20.4 ± 0.4	20.1 ± 0.8	14.0 ± 0.4	21.2 ± 1.0	12.7 ---	21.9 ---
V_0(km s^{-1})	− 1.65 ± 0.2	0.9 ± 0.8	--- ---	− 1.6 ± 0.2	0.9 ± 0.3	1.0 ± 0.4	1.0 ± 0.3	− 1.6 ± 0.2	0.9 ± 0.8	+ 2.5 ---	--- ---
σ(km s^{-1})	1.5	2.2	2.2	1.6	2.2	2.5	2.1	1.6	2.2	---	---
$a \sin i$(a.u.)	4.17 ± 0.15	6.23 ± 0.26	10.37 ± 0.25	4.17 ± 0.11	6.20 ± 0.15	6.16 ± 0.19	6.07 ± 0.27	4.09 ± 0.15	6.20 ± 0.30	4.3 ---	7.5 ---

[a] The 1932 observation is assumed to be after periastron passage (P_1) or before it (P_2).
[b] Epoch of periastron passage.

Notes to TABLE II

Solutions: (The two-prism velocities are included only in solution (2). In evaluating $a \sin i$, P_1 is employed.)
(1) General solutions.
(2) Solution employing velocity differences.
(3) P, T, E, and ω adopted from solution (2).
(4) P, T, E, and ω adopted from the V_c solution (1).
(5) Same as solution (4), but with the 13 observations between JD 30286 and 30807, having the largest orbital velocities, omitted. See the text.
(6) Preferred elements, with uncertainties estimated from the results for the other solutions.
(7) McLaughlin's (1948) elements. From his notes, it appears that McLaughlin may not have applied the curvature correction of − 1.0 km s^{-1}.

of these 1σ variations on the other elements are negligible. The uncertainties in the orbital dimensions and in the masses resulting from the dichotomy in the period are considerably less than those resulting from uncertainties in the orbital eccentricity and in the values of K, the amplitudes of velocity variation.

The basis for each of the solutions in Table II is given in the notes following the table. Values of P, T, e, and ω are usually best determined from the differences in the velocities of the components (solution 2 in Table II) when the two sets of velocities are of comparable weight, as they are in this case. It is, nevertheless, possible that the values of V_h are, despite the apparent symmetry of the core of its K line, subject to systematic effects as a consequence of distortion by the broad K line of the cool star (Fig. 1). The difference in the eccentricities for the two components in solution (1) of Table II could be caused in part by such an effect. Solutions (4) and (5) employ different assumptions about possible systematic effects, which may be expected to be greatest when the velocity difference is a maximum, near periastron. The effects on the masses ($\mathscr{M}$) and orbital dimensions (a) are less than their statistical uncertainties. In the adopted solution (6), the estimated uncertainties, particularly in the eccentricity, have been increased over their formal values to allow for these effects.

The difference of 2.5 ± 0.8 km s^{-1} between the systemic velocities of the two components may be a consequence, at least in part, of the scheme used for adjusting the wavelengths of the lines employed for the velocities of the cooler star.

The residuals listed in Table I are relative to the preferred solution (6) in Table II for the longer period. The difference between the velocities predicted for the two periods never exceeds 0.2 km s^{-1} and is much less in the mean. The observed velocities (one-prism results only) and curves based on the preferred elements are shown in Figs. 2 and 3. In the latter, the variation through periastron is shown with an expanded timescale. Since the solutions represented by the curves in the figures (solutions 6 of Table II), are compromises, differing from the individual best-fit solutions (solutions 1), systematic runs in the residuals may be seen. The two phases for the encircled 1932 velocities correspond to the two periods, 5346 days (larger phase) and 5277 days. In the best-fit solutions, the 1932 velocities fall almost precisely on the predicted curves, since nearly all the weight of the derived period lies upon them. It is unfortunate that no velocities are available from either of the periastron passages in 1963 or 1976. The next occurs in 1991. Not only are improved periods desirable, but so are more nearly definitive spectroscopic elements.

That the minimum masses derived by McLaughlin (4.9 and 2.9 $\mathscr{M}_\odot$) are considerably greater than those obtained by us (3.0 and 2.0 $\mathscr{M}_\odot$) is not owing to any systematic effect in McLaughlin's measures. His value of $K_c + K_h$, 34.6 km s^{-1}, is close to our value, 35.2. The reason is, rather, the difference between the orbital eccentricities in the two investigations, to which the masses are very sensitive for such large eccentricities. In his analysis, McLaughlin employed only 34 of the 78 plates used in this investigation. Furthermore, only 12 of the 33 plates obtained during the period of most rapid velocity variation in 1947 were included, and of these, none covers the later phases of the rapid variation.

III. ASTROMETRIC ORBITS

The history of the resolution of Gamma Persei has been presented by McAlister (1982). The measurements made in 1939 by Wilson (1941) with a visual Michelson interferometer are the result of Wilson's attempt to resolve stars of composite spectra and predated McLaughlin's orbit analysis by a decade. Although Wilson's results cannot contribute to the analysis of the visual orbit when combined with the considerably more accurate speckle observations now available, it is almost certain that Wilson did indeed detect duplicity in

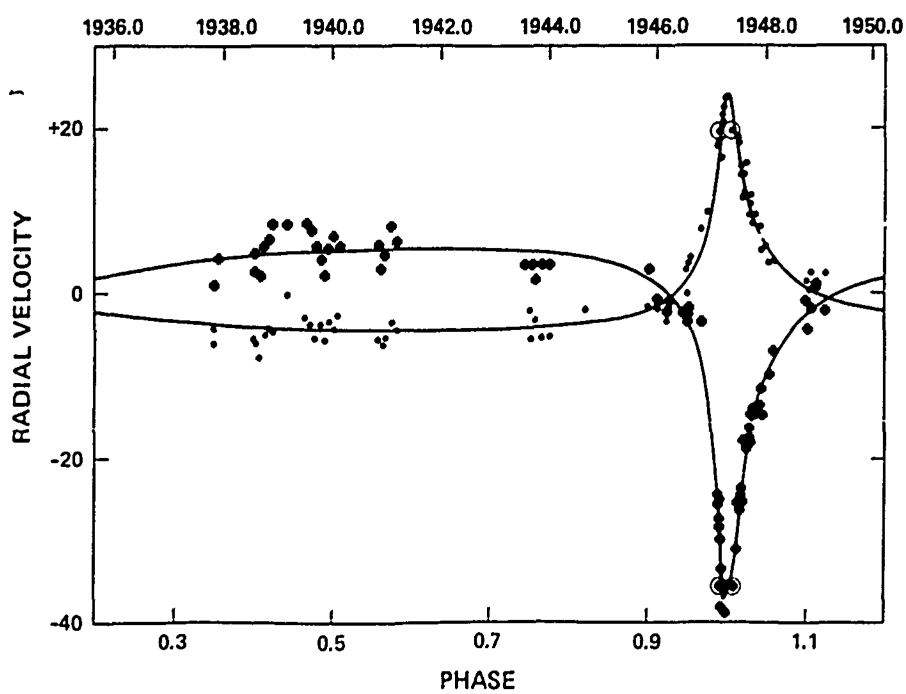

FIG. 2. Velocities of the components of γ Per from Michigan pl.tes. Dots: the G giant; pluses: the K line of the A star. The encircled points are for the 1932 plate for two periods. See the text. The curves are from the adopted solutions (6) in Table II. Phases are fractions of the period after periastron passage.

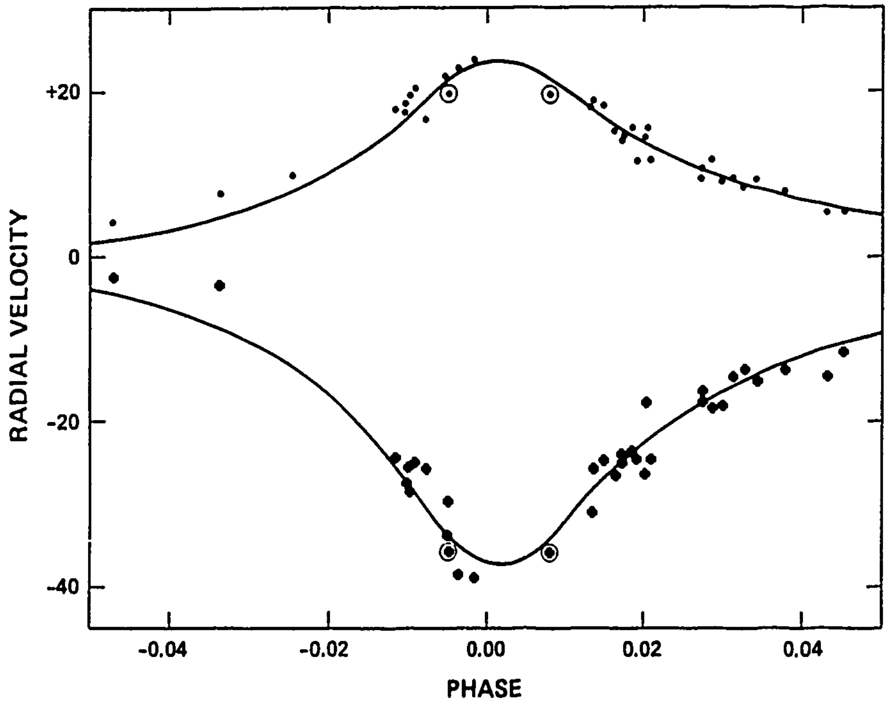

FIG. 3. Velocities of the components of γ Per during their passage through periastron. Explanation as for Fig. 2.

his visibility estimates as evidenced by the residual to his position-angle measure. This is an impressive feat considering the magnitude difference in the system and the small aperture (18 in.) of the telescope he employed in his observing program.

The number of speckle observations has nearly tripled since the last astrometric analysis (McAlister 1982), so that 35 such measures are now available. The collected measurements of position angles and angular separations along with the original sources are shown in Table III. They give the position of the A star relative to the G star. The majority of these observations were obtained at the 4 m telescope on Kitt Peak as a part of the ongoing Georgia State University speckle program. The GSU speckle data prior to 1982.0 were obtained with a photographic speckle camera, while those after 1982.0 were produced by an ICCD-based speckle camera. In the case of these observations, the two sets of data are of comparable accuracy. The single measurement by Tokovinin (1985), a fine observation with small residuals, was made with a "phase grating" interferometer on a telescope with an aperture of 1 m. By contrast, an aperture as large as 6 m was employed by Dudinov *et al.* (1982) and Balega and Balega (1985). It is our experience that for separations exceeding two or three times the diffraction limit, the accuracy of the measurement is more dependent upon the quality of the calibration than on an increase in aperture. In general, we find that the early observations from any particular speckle group have large errors in both position angle and angular separation, and that these errors are significantly diminished in subsequent observations as calibration techniques are improved.

The elements of the "visual" orbit for γ Per were calculated with a computer program developed by Hartkopf (Hartkopf *et al.* 1987). This method permits the assignment of formal errors to the geometric quantities a'', i, ω, and Ω, but does not provide error estimates for P, T, and e. We have decided to base our conclusions for γ Per solely on the observations by McAlister and his colleagues (the GSU/CHARA data). They form a homogeneous set and have much smaller scatter than the other observations, as seen in Table III and Figs. 4 and 5. Systematic differences between the two sets are also apparent. These differences are probably due to the lack of absolute calibration for scale and position angle. The GSU/CHARA observations are, on the other hand, well calibrated by means of the double-slit mask scheme described by McAlister *et al.* (1978b).

In the analysis of the GSU/CHARA data, the values of P and T are adopted from the spectroscopic results (solutions 6 of Table II) because of the considerably greater time interval covered by the spectroscopic than by the interferometric observations. The results of the analysis are given as solutions 1 and 2 of Table IV. Also given is a solution (solution 3) in which the most deviant GSU/CHARA observation is omitted. Finally, we list a solution (solution 4) in which all elements, including P and T, are derived from all the speckle observations. In this solution, each GSU/CHARA is given twice the weight of each of the others. Although only 63% of an orbital period is covered and periastron is outside the time interval, the good coverage around the apastron passage of 1983.67, along with the highly eccentric orbit, gives the observations leverage in determining the elements P, T, and ω. The period derived is only 0.3% shorter than the longer of the two spectroscopic periods. It is on this basis that we prefer the 1.3% longer of the spectroscopic periods. In fact, all the elements in common between the completely independent astrometric and spectroscopic solutions agree within their uncertainties, a result indicating a very high level of consistency between the two complementary approaches to orbit determination.

The observations recorded in Table III are shown in Figs.

TABLE III. Interferometric observations of γ Per.

t	θ(°)	ρ(")	Δθ(°)	Δρ(")	W	Source
1939.77	49.4	0.07	-15.4	-0.178	0.0	Wilson (1941)
1973.450	59.0	0.193	- 5.8	+0.014	0.0	Labeyrie et al. (1974)
1975.629	83.0	0.052	+18.7	-0.002	0.0	Blazit et al. (1977)
1975.782	51.0	0.041	-13.1	+0.001	0.0	Blazit et al. (1977)
1975.956	----	<0.033	(63.8)	(0.024)	---	McAlister (1978)
1976.857	----	<0.035	(244.1)	(0.017)	---	McAlister (1978)
1976.860	----	<0.035	(244.0)	(0.017)	---	Hartkopf and McAlister (1980)
1976.923	----	<0.035	(243.2)	(0.012)	---	McAlister (1978)
1977.087	----	<0.035	(75.4)	(0.003)	---	McAlister (1978)
1977.734	67.0	0.054	+ 1.2	-0.003	1.0	McAlister and Fekel (1980)
1977.742	65.4	0.058	- 0.4	+0.001	1.0	McAlister and Fekel (1980)
1977.919	65.8	0.066	+ 0.2	-0.004	1.0	McAlister and Henry (1982a)
1978.149	66.5	0.091	+ 1.0	+0.005	1.0	McAlister and Fekel (1980)
1978.616	64.8	0.114	- 0.6	+0.000	1.0	McAlister and Fekel (1980)
1978.618	64.7	0.115	- 0.7	+0.001	1.0	McAlister and Fekel (1980)
1979.036	64.2	0.133	- 1.2	-0.003	1.0	McAlister and Hendry (1982b)
1979.533	65.2	0.157	- 0.1	-0.002	1.0	McAlister and Hendry (1982b)
1979.771	64.2	0.168	- 1.1	-0.001	1.0	McAlister and Hendry (1982b)
1980.153	64.9	0.181	- 0.4	-0.002	1.0	McAlister et al. (1983)
1980.724	64.7	0.200	- 0.5	-0.001	1.0	McAlister et al. (1983)
1980.726	65.1	0.207	- 0.1	+0.005	1.0	McAlister et al. (1983)
1980.729	61.8	0.202	- 3.4	+0.000	1.0	McAlister et al. (1983)
1980.775	63.3	0.200	- 1.9	-0.003	0.0	Dudinov et al. (1982)
1980.893	64.6	0.209	- 0.6	+0.003	1.0	McAlister and Hartkopf (1984)
1980.896	64.3	0.216	- 0.9	+0.010	1.0	McAlister and Hartkopf (1984)
1981.671	53.0	0.284	-12.2	+0.059	0.0	Balega et al. (1984)
1982.758	64.8	0.237	- 0.4	-0.004	1.0	McAlister et al. (1987b)
1982.766	64.7	0.240	- 0.5	-0.002	1.0	McAlister et al. (1987b)
1983.047	65.6	0.243	+ 0.5	-0.002	1.0	McAlister et al. (1987b)
1983.711	65.9	0.247	+ 0.8	-0.001	1.0	McAlister et al. (1987b)
1983.713	65.8	0.246	+ 0.7	-0.003	1.0	McAlister et al. (1987b)
1983.824	61.3	0.262	- 3.8	+0.013	0.0	Balega and Balega (1985)
1983.931	64.0	0.270	- 1.1	+0.021	0.0	Bonneau et al. (1984)
1983.937	65.0	0.260	- 0.1	+0.011	0.0	Bonneau et al. (1984)
1983.958	63.4	0.253	- 1.7	+0.004	0.0	Balega and Balega (1985)
1984.060	65.3	0.245	+ 0.2	-0.004	1.0	McAlister et al. (1987b)
1984.786	64.5	0.254	- 0.6	+0.007	0.0	Tokovinin (1985)
1984.934	62.5	0.258	- 2.6	+0.012	0.0	Bonneau et al. (1985)
1985.005	65.3	0.247	+ 0.2	+0.001	1.0	McAlister et al. (1987b)
1985.838	65.0	0.239	- 0.1	+0.002	1.0	McAlister et al. (1987b)
1986.886	64.7	0.219	- 0.3	+0.003	1.0	McAlister et al. (1987a)

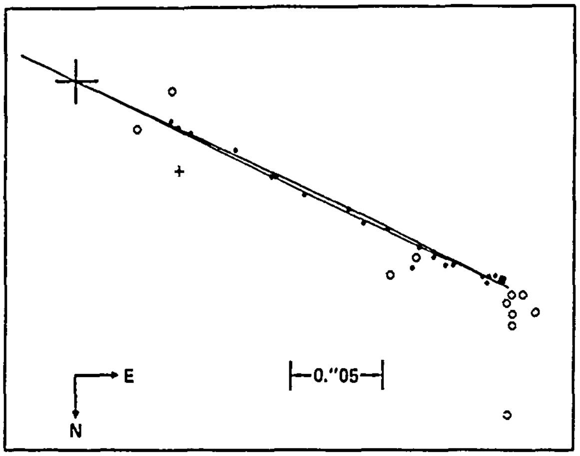

FIG. 4. Astrometric observations of γ Per. Dots: GSU/CHARA observations; light circles: other speckle observations; plus: Wilson's (1941) visual observation. The curve is from solution (1) of Table IV. The upper branch is for the interval preceding apastron passages. The large cross represents the primary (cooler) component.

4 and 5, along with the corresponding curves from the preferred solution. The inclination of the orbital plane even permits the possibility of an eclipse at minimum angular separation. There is a high probability of observing some level of eclipse phenomena at the next times of predicted minimum separation around 1990.89 and 1991.70.

IV. PROPERTIES OF THE STARS

The agreement between the independently determined values of P, T, e, and ω from spectroscopic (solution 6 of Table II) and interferometric (solution 3 of Table IV) observations is very good. The adopted orbital parameters are listed in Table V. The period and first value of T are from the spectroscopic results, upon which the second value of T is based. It is not determined precisely enough from the speckle observations alone for an improved determination of the period. The adopted values of e and ω are compromises. The values of a'', K, V_0 and a are derived with P, T, e, and ω held fixed. The adopted values of K, V_0 and a differ slightly from those of solution (6) in Table II since slightly different values of e and ω are used in analyzing the velocities. The uncertainties listed are intended to be realistic values. While the values of K_c and K_h are sensitive to the adopted value of e, the values of the critical quantity, $a \sin i$, are very insensitive to e over the range of values of e in the tables.

The value of the parallax, 0".0135 ± 0".0007, obtained by combining astrometric and spectrographic results, is in reasonable, though not particularly significant, agreement with the directly determined value, 0".011 ± 0".006. The corresponding distance modulus is 4.35 ± 0.1 mag. The combined apparent magnitude is $V = 2.93$ (Johnson *et al.* 1966).

In his multifilter photometric study of stars with composite spectra, Bahng (1958) discussed the case of γ Per in considerable detail. He concluded that the best fit was to stars of spectral types G8 III and A3 V, with a magnitude difference $\Delta M_V = 1.4$, the G star being more luminous. As a partial test of this value, one may employ the $B-V$ and $U-B$ indices of γ Per, $+0.70$ and $+0.45$ (Johnson *et al.* 1966), and of the standard stars used by Bahng in fitting the radiation of γ Per (λ Gem, A3 V; κ Gem and η Psc, G8 III). Differences of 1.3 and 1.5 mag between the components of γ Per reproduce the values of both $B-V$ and $U-B$ for the star within 0.02 mag, while values outside this range do not, in agreement with Bahng's result. We adopt $\Delta M_V = 1.4 \pm 0.2$ mag and obtain $M_V = -1.1 \pm 0.25$ and $+0.3 \pm 0.3$ for the G and A stars, respectively.

Published estimates of the spectral types in γ Per are G8 III: + A3 (W. W. Morgan in Stebbins and Kron 1956) and K0 III + A2 (Cowley 1976). On the basis of examination of two Lick 16 Å mm^{-1} spectrograms of γ Per, the cool star cannot be as early as G5 nor as late as K0, and its luminosity is less than class II and greater than class IV. From the appearance of the K line of the hotter star (Fig. 1), its type is in the range A2–A3. These estimates are in excellent agreement with those from Bahng's analysis and lend further credence to them.

In order to obtain the luminosities, radii, and surface gravities of the components, we require effective temperatures T_e and bolometric corrections B.C. As the basis for these quantities, we adopt the color indices of the stars employed by Bahng (1958) as the counterparts of the components of γ Per. His A3 V standard was λ Gem, having $B-V = +0.12$, leading to $\log T_e = 3.919$, B.C. $= -0.1$ mag (Popper 1980, Table I). The G8 III standards were κ Gem and η Psc. For cool giants, Ridgway *et al.* (1980) have

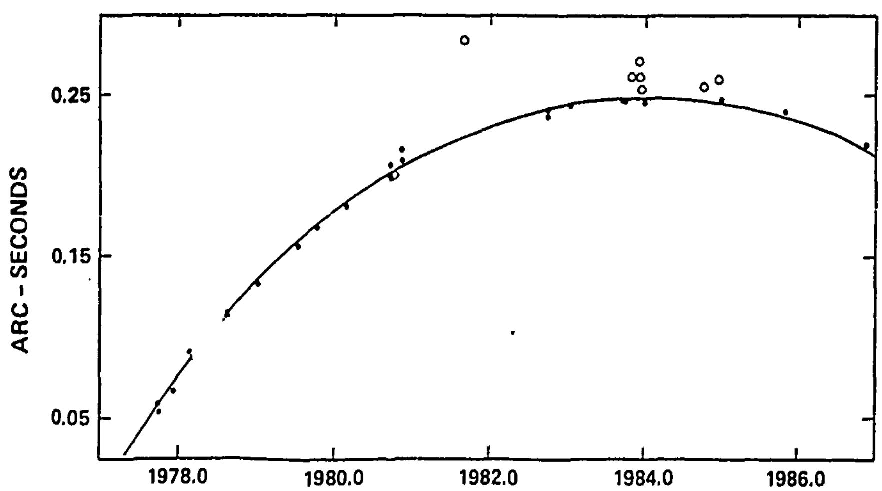

FIG. 5. Separations ρ of the components of γ Per. Symbols as in Fig. 4. The curve is from solution (1) of Table IV.

TABLE IV. Solutions to the visual orbit.

	Solution			
Element	1	2	3	4
P(y)	14.637	14.448	14.637	14.593
T(y)	1976.579	1976.579	1976.579	1976.548
e	0.784	0.792	0.784	0.782
a"	0.140 ± 0.002	0.140 ± 0.003	0.140 ± 0.002	0.142 ± 0.003
i(°)	90.49 ± 1.14	90.49 ± 1.14	90.22 ± 0.92	90.23 ± 1.22
ω(°)	355.3 ± 1.1	353.0 ± 1.1	355.2 ± 1.0	353.2 ± 1.2
Ω(°)	245.2 ± 1.1	245.2 ± 1.1	245.2 ± 1.0	244.7 ± 1.2
σ_x(")	± 0.0034	± 0.0034	± 0.0026	± 0.0041
σ_y(")	± 0.0033	± 0.0033	± 0.0032	± 0.0033

Solutions:

1. P(longer) and T adopted from spectroscopic solution no. 6. CHARA observations only. Preferred solution.
2. P(shorter) and T adopted from spectroscopic solution no. 6. CHARA observations only.
3. As solution 2, with observation in 1980.729 omitted.
4. Based upon speckle observations since 1977.0.

shown the Johnson $V-K$ index to correlate well with T_e. The values of this index are 2.11 and 2.19 for κ Gem and η Psc, respectively (Johnson *et al.* 1966). The adopted value of log T_e is 3.715, based on the re-examination by Wing *et al.* (1985) of the Ridgway *et al.* (1980) scale.* The corresponding bolometric correction is -0.3 mag.

The properties of the components are compiled in Table VI. The uncertainties in the temperatures, and consequently in the radii R and surface gravities g, include effects from uncertainties in the color indices, but not from uncertainties in the temperature scales themselves, which we are unable to estimate.

V. DISCUSSION

The cool giant in γ Per takes its place along with those in α Aur ($\mathscr{M} = 3.3\mathscr{M}_\odot$, Shen *et al.* 1985) and ϕ Cyg ($\mathscr{M} = 2.5\mathscr{M}_\odot$, McAlister 1982) as having directly determined masses. Both components of γ Per have masses well within the ranges found for other stars of their spectral types and are not overmassive, as had appeared to be the case with McLaughlin's minimum masses. On the other hand, as noted by Bahng (1958) on the basis of the trigonometric parallax and by McAlister (1982), the stars appear to be considerably more luminous than expected from the spectral types. According to a recent discussion by Keenan (1985), the average absolute magnitudes M_V for A3 V and for G8 III

*The temperature scale for cool giants in Popper (1980) was prepared before the work of Ridgway *et al.* (1980) became available. Popper's values of T_e are lower than the values of Wing *et al.* (1985) by several hundred K. Discussions of binaries (e.g., Popper 1976), as well as of other topics in which the lower scale was employed, require re-evaluation.

TABLE V. Adopted orbital parameters.

P(y)	14.64	± 0.05
T(y)	1947.30	± 0.02
	1976.6	± 0.1
e	0.79	± 0.02
ω(°)	353	± 1.5
i(°)	90.5	± 1.3
Ω(°)	245.2	± 1.2
a''	0.140	± 0.004
K_c (km s^{-1})	13.7	± 0.5
K_h (km s^{-1})	20.5	± 1.0
Vo_c (km s^{-1})	− 0.7	± 1.0
Vo_h (km s^{-1})	+ 2.0	± 1.0
a_c (a.u.)	4.17	± 0.15
a_h (a.u.)	6.18	± 0.30

are +1.2 and +0.3, respectively. Thus, the stars (Table VI) are more luminous than these standard values by 1.0 and 1.4 mag. The uncertainties in Table VI are realistic ones, and the observations do not permit the luminosities to be as [illegible] as the standard values for the estimated types. While the [illegible]ture classes of the components of γ Per are well es-[illegible]d, some uncertainty exists in the luminosity classes. The standard absolute magnitudes for A3 III and G8 IIIa, for example, are +0.3 and −0.8, respectively (Keenan 1985). If we take into consideration cosmic scatter as well as the observational uncertainties, the observed luminosities are not completely unreasonable.

One might expect to obtain an estimate of the luminosity class of the A star from the confluence of the higher members of the Balmer series. However, in that region of the spectrum, the flux from an early A star falls with decreasing wavelength more rapidly than the flux of a G8 giant. For example, the Strömgren index $v-b$ is about +0.8 for G8 III and +1.2 for A3 V, and the hydrogen lines of the A star are lost in the welter of strong metallic lines of the G star. Satellite ultraviolet observations should be free of this difficulty. The components of the visual binary ϕ Cyg have approximately the same temperature class as the cool star in γ Per, and its mass and luminosity are also well determined (McAlister 1982). Its surface gravity is approximately 0.8 dex greater than that of the more luminous cool giant in γ Per. This difference should be testable through differential analysis of high-resolution spectra of the stars as a further check on the luminosity of the γ Per giant.

The closest counterpart to the A star in γ Per among binaries with well-established properties is the hotter component of the evolved A type binary SZ Cen (Popper 1980), $\mathscr{M} = 2.3\mathscr{M}_\odot$, $R = 3.6\,R_\odot$. The G giant is over one magnitude more luminous than its counterpart of comparable mass in α Aur.

While it is possible to fit the properties of each component of γ Per reasonably well to published post-main-sequence evolutionary tracks, the ages of the two stars evaluated in this way differ by a factor of 2 or more. This discrepancy was pointed out by McAlister (1982). The fundamental difficulty is that each star would appear to be in a short-lived stage of post-main-sequence evolution, but the more massive star should have completed its passage through all phases of the giant configuration before the less massive star became appreciably evolved. The rate of evolution is so highly mass dependent that, even with the uncertainties in the masses and other properties taken into consideration, as well as in evolutionary calculations, the serious discrepancy remains. For example, according to Iben's (1967) tracks, the A star is starting to move rapidly across the Hertzsprung gap at an age of 8×10^8 yr, while the G giant has completed its rise to the first giant tip, has left the giant branch, and is approaching it for the second time, with an age of 3×10^8 yr. No rational treatment of the observations can alleviate the dis-

TABLE VI. The components of γ Per.

	A star		G giant	
M_V	+0.3	± 0.3	−1.1	± 0.25
log L($L_\odot$)	+1.80	± 0.20	+2.44	± 0.15
log T_e(K)	3.92	± 0.02	3.715	± 0.015
R($R_\odot$)	3.9	± 0.3	21	± 4
m($m_\odot$)	2.03	± 0.15	3.06	± 0.30
log g (cm s^{-2})	3.6	± 0.2	2.3	± 0.2

crepancy significantly. In order for the A star to remain well within the main-sequence band, at $M_V = +1.2$, for example, the parallax would have to be increased from 0".014 to 0".022. Conformity to available evolutionary tracks would require an even greater parallax. However, the observed parallax, 0".011 ± 0".006, is in good agreement with the value derived from the binary star analysis. Much more significantly, the ratio of the angular semimajor axis of the relative orbit a'' to the linear value a would have to be increased by nearly 60%. With cos ω close to unity, the value of a'' is given simply by $\rho_{max}/(1+e)$. As seen in Fig. 5, ρ_{max} cannot exceed 0".26, and even with e as small as the unacceptable value 0.7, a'' is increased by less than 10% over the adopted value. With respect to the linear value a, as noted earlier, it is insensitive to the adopted value of e. It is not possible for the velocity variation of either star to be decreased significantly from the adopted results. Any systematic effect resulting from distortion of the profile of the K line in the A star spectrum by the profile in the G star could only require an increase in the size of the orbit over that derived, a change in the opposite sense from that required.

Of the various possible escapes that might be imagined from this dilemma in the timescales (e.g., the A star is in a state of pre-main-sequence contraction; the components are not the same age and became gravitationally bound some time after their formation; the A star has suffered mass loss recently; rapid rotation in the interior of the G giant has slowed its evolution, etc.), the most plausible might be that the G star has an undetected close companion of mass, say, $0.7\mathscr{M}_\odot$. Then the timescales for evolution of the 2.0 and 2.3 $\mathscr{M}_\odot$ stars would be more nearly equal, with the G giant in a more advanced stage. Owing to the speculative nature of these hypotheses, we refrain from further attempts to specify the evolutionary history. An observational test of the triple-star hypothesis would be to look for shorter period variation in the velocity of the G giant. Another possible test would be the surface gravity of the G giant, evaluated by spectroscopic analysis. The gravity would be less than the value in Table VI.

We point out, finally, that all our understanding of the rate of stellar evolution through the giant region, as dependent on mass, comes exclusively from model calculations, with almost no direct tests of the kind that appear to fail us in the case of γ Per. A dilemma of the same kind, although not so severe because the masses are more nearly equal, exists for α Aur (e.g., Shen *et al.* 1985). We have previously noted (Popper 1980; McAlister 1982) another potential disagreement between observations and generally accepted theory, namely that, on the basis of the small number of masses of cool stars of luminosity class III, the expected concentration of masses below $2\mathscr{M}_\odot$ is not found.

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ICCD SPECKLE OBSERVATIONS OF BINARY STARS. IV. MEASUREMENTS DURING 1986–1988 FROM THE KITT PEAK 4 m TELESCOPE

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ABSTRACT

One thousand five hundred and fifty measurements of 1006 binary star systems observed mostly during 1986 through mid-1988 by means of speckle interferometry with the KPNO 4 m telescope are presented. Twenty-one systems are directly resolved for the first time, including new components to the cool supergiant α Her A and the Pleiades shell star Pleione. A continuing survey of *The Bright Star Catalogue* yielded eight new binaries from 293 bright stars observed. Corrections to speckle measures from the GSU/CHARA ICCD speckle camera previously published are presented and discussed.

I. INTRODUCTION

This paper presents further results from a continuing program of binary star speckle interferometry carried out at the 4 m Mayall telescope at Kitt Peak National Observatory. A detailed description of the observational technique and instrumentation, and of the methods of data reduction, analysis, and calibration, can be found in Paper II (McAlister *et al.* 1987b) of this series. We have employed those same methods to derive the results presented here.

II. CALIBRATION REVISIONS

In the course of the reduction of the observations obtained for this paper and in a series of analyses of binary star orbits based upon all of our previously published speckle data, we have found it necessary to revise the calibration basis for the measurements published in the three earlier papers of this series (McAlister *et al.* 1987a,b; Lu *et al.* 1987). The calibration of our speckle observations continues to be based upon the insertion of a double-slit mask at a pupil to produce a fringe pattern within speckle images and is carried out exactly in the manner described in McAlister (1977), the initial paper from the speckle program begun by the first author in 1975. The mask is aligned E–W and the speckle camera is mounted at the Cassegrain focus so that north is in the Y direction; thus the fringe pattern produced by the double-slit mask provides a spatial calibration in the X coordinate. This method of determining the scale and orientation calibration has served very well as a truly external means of converting the linear measures from speckle power spectra or autocorrelograms into angular measures on the sky. The revision we describe here has three distinct causes.

The greatly expanded collection of calibration data now available to us shows that the scale value at the speckle focal plane of the ICCD camera has been remarkably constant since the digital camera was first used in 1982 at the 4 m telescope. This has enabled us to determine a mean scale that has the primary effect of increasing the angular separations for our data obtained during 1983–1984 by 1.5%, changes to other epochs being insignificantly small. The larger change for the 1983–1984 data is due to the somewhat lower quality of the calibration data available for that particular time period. We now adopt a calibration based upon the mean of all the scale and orientation measurements that we have determined since the initiation of our ICCD speckle-camera system.

Using a laboratory spectrometer, we have carefully determined the effective wavelength of the Strömgren y filter used for the calibration observations. A correction for the temperatures of the individual calibration stars was also determined by convolving the filter response against blackbody curves appropriate to the stars we observed. Although the shift in the y effective wavelength is small, amounting to an overall difference in scale of 0.1%, we did find the scatter to be measurably reduced among the collected scale values once this temperature effect was included. We point out that there is no corresponding temperature effect for the program stars; thus it is not necessary to apply a temperature correction for stars other than calibration stars.

Residuals to newly determined double star orbits for some two dozen binaries showed a consistent discontinuity at the transition between the old photographic speckle data and the new ICCD data. A thorough investigation of this effect showed that the cause of this step distribution of the residuals is due to the effective pixel geometry as determined by the autocorrelator. Although the CCD has pixels that are square, the final pixel shape is determined not by the chip but by the redigitization done by the autocorrelator. The CCD camera electronics reads out the chip and converts the digital information into an analog video signal, specifically into standard RS-170 video. The autocorrelator then digitizes the video into approximately the same format as exists on the CCD, but, we discovered, with a slight timing mismatch so that one unit in Y is not exactly equal to one unit in X. The precise mismatch was measured simply by rotating the camera 90° and taking calibration and binary star data in the orthogonal direction. Analysis of these data gave a correction factor for the nonsquare pixelation such that

$$Y/X = 1.0351 \pm 0.0030.$$

This effect is therefore position-angle dependent.

In Fig. 1 we show residuals for two binary star systems before and after the combined calibration effects discussed

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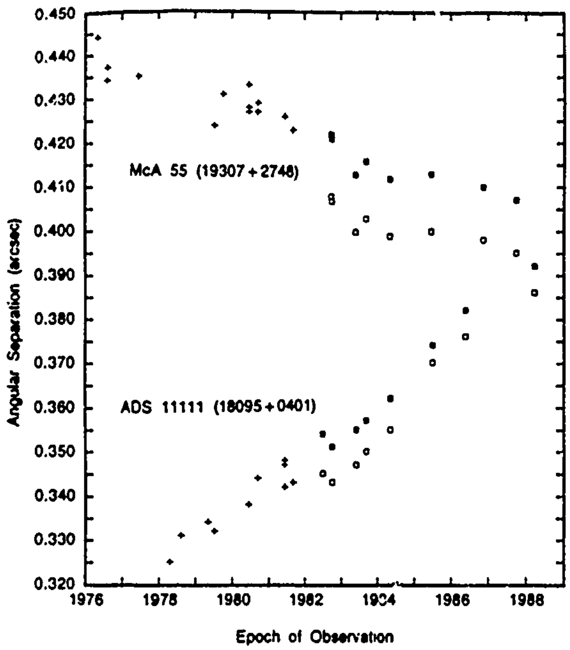

FIG. 1. The effect of the correction for nonsquare pixelization resulting from the digitization by the vector autocorrelator is shown for two binary star systems. In both cases, the plus signs are for angular-separation measures determined from speckle data obtained prior to 1982 using a photographic speckle-camera system, light squares are measures from the ICCD camera and autocorrelator before scale correction, and dark squares are the corrected measures. The scale correction clearly eliminates the discontinuity apparent in uncorrected data. During the observation interval, McA 55 decreased in position angle from 190° to 160°, while ADS 11111 changed from 340° to 315°.

above are applied to the data. The agreement between the older photographic material and the more recent ICCD data is greatly improved by correcting the data for the effects described above. The average change in angular separation is approximately an increase by 2.5%, while the average change in position angle is about 0°.5. The corrected values of our earlier ICCD data can be obtained upon request from the authors in the form of a *Second Catalog of Interferometric Measurements of Binary Stars* (McAlister and Hartkopf 1988) or from the *Washington Double Star Catalog* (WDS) maintained by Charles Worley at the U. S. Naval observatory. We chose to disseminate the revised measures in this manner rather than by publishing somewhat complicated correction formulas or by republishing complete tables of the earlier results because most users of double star measures request a complete listing of all measures of a given system, regardless of their technique of origin, from the WDS.

III. NEW MEASUREMENTS

The GSU ICCD speckle camera was scheduled for 25 nights during five observing sessions between May 1986 and May 1988. On these nights, 3636 series of observations were accumulated during 221 hr suitable for speckle interferometry. The average observation rate was thus 16.4 stars per hr. A typical observational sequence consists of 90 s of data acquisition at standard video rates, the individual exposures controlled by gating the high voltage on the microchannel plate tube to 15 ms. The Strömgren *y* filter is usually used, except for fainter objects, when a wider-bandwidth filter centered on *y* is employed. Magnification optics yielding approximate scales of 0.0052 or 0.0088 arcsec per pixel were normally used, except during the rare periods of very poor seeing (average stellar profile FWHM in excess of 3 arcsec) when a lowest magnification of 0.016 arcsec per pixel is used and then only for more widely separated and brighter binaries. Vector autocorrelograms were produced in real time at the telescope and subsequently reduced and analyzed in the CHARA image-processing laboratory at GSU in Atlanta.

Table I contains observational and catalog information for the 21 newly resolved stars presented in this paper. As was initiated in Paper II, we assign each newly resolved star a CHARA number that continues from the last number assigned in Paper III. Two hundred fifteen systems have been newly resolved to date in this continuing program. The last column in Table I shows whether the system is a spectroscopic (SB), composite spectrum (Spm), or occultation (Occ) binary, a third component discovered in the course of observing a previously known visual binary (Tri), a newly discovered binary resulting from a survey of *The Bright Star Catalogue* (Hoffleit 1982), or a Ba II star discovered as a result of our attempts to find binaries among this class of stars. Two stars in the Pleiades cluster have been newly resolved, the first (HD 23568) being indicated as double from occultation observations and the second being the famous shell star Pleione, which *The Bright Star Catalogue* notes as being a suspected long-period spectroscopic binary. We have observed Pleione on several occasions during the last few years without having detected this companion. These negative results do not contradict the present observation in which the weak autocorrelation peak indicates a large magnitude difference, a situation in which seeing and instrumental parameters make detection problematic.

We also report a new companion to the M5 Ib–II star α Her A, the brightest member of the system ADS 10418. The B component of the previously known system is itself a composite-spectrum star. Reasonable assumptions regarding the mass of the cool supergiant and the distance to the star lead to a rough estimate of 100–150 yr for the period of the newly discovered companion. We have learned from Dr. Myron A. Smith (private communication) that his radial-velocity measures for α Her A during the last 4 yr have shown an increase in velocity by about 11 km/s during a 3 yr interval, with an apparent turnover in velocity during the fourth year. This suggests yet another component with a period of the order of a decade. Thus this system may, in fact, have five physical components.

The new speckle measurements of binary stars are presented in Table II, where we continue the format used in Paper II. This collection contains several measurements from 1985 that were omitted in Paper II, including the two newly resolved Ba II stars (CHARA 129 and 140) that were observed as a supplement to the survey of high-velocity stars for which details have been published in Paper III. Two measurements are also given for HR 6168 (σ Her) from 1977 that were obtained with the photographic speckle camera, the instrument used to collect data for the series of speckle observations that ended with the paper by McAlister *et al.* (1984). The HR 6168 result for 1977.1781 is a previously unpublished measure, while that for 1977.3284 is a correction of the position-angle value that was originally published. While the coordinates in Table II are for equinox 2000.0, the position angles have not been corrected for precession and are thus based upon the equinox for the epoch of observation shown as the fraction of the Besselian year.

TABLE I. Newly resolved binary stars.

CHARA Number	HR/DM	Name	HD	SAO	ADS	α, δ (2000)	V	Spect. Class.	Disc. Sep.	Binary Type
121	9097	—	225094	10942	—	00034+6339	6.24	B3Iae	0.196	BSC
122 Aa	9105	—	225218	36037	30	00046+4206	6.01	B9III	0.110	BSC
123	63	θ And	1280	53777	—	00171+3841	4.61	A2V	0.057	BSC
124	+24°562	—	23568	76183	—	03470+2431	6.81	B9.5V	0.208	Occ.,Pleiad
125	1180	28 Tau	23862	76229	—	03492+2408	5.09	B8Vpe	0.217	Pleiad
126	1176	—	23838	39134	—	03501+4458	5.66	G2III+F2:V	0.031	SB
127 Aa	—	—	31033	76811	3501	04536+2522	7.2	AO	0.075	Tri.
128 Aa	2257	4 Lyn	43812	25678	4950	06221+5922	5.94	A3V	0.187	Tri.
129	2392	—	46407	151625	—	06328−1110	6.24	K0III:Ba3	0.161	BaII
130	+19°2069	—	73712	98019	—	08402+1921	6.78	A9V	0.088	Occ.
131	3635	—	78661	98400	—	09098+1134	6.48	F2Vp	0.089	Occ.
132 Aa	−23°9339	—	91172	178922	7809	10311−2411	7.5	F3+A5	0.110	Spm.
133	4380	55 UMa	98353	62491	—	11191+3811	4.78	A2V	0.068	BSC
134	4528	4 Vir	102510	119058	—	11479+0815	5.32	AI	0.259	BSC
135	4632	3 Com	105778	99973	—	12105+1649	6.39	A4V	0.262	BSC
136	4642	—	106022	82181	—	12120+2832	6.49	F5V	0.209	BSC
137	5372	—	125632	29098	—	14189+5452	6.53	A5Vn	0.103	BSC
138 Aa	6130	—	148374	17073	10052	16238+6142	5.67	G8III	0.211	Tri.
139 Aa	6406	α Her	156014	102681	10418	17146+1423	3.48	M5Ib−II	0.192	BSC
140	+10°3801	—	178717	104535	—	19094+1014	7.10	K4III:Ba4	0.250	BaII
141	+00°4982	—	219420	128069	—	23157+0119	6.8	F5	0.061	Occ.

We emphasize that speckle interferometry does not, through autocorrelation or power-spectrum analysis, reveal the true quadrant of the secondary. Therefore all quadrants are potentially ambiguous by 180° in position angle. Speckle images preserve the true quadrant information as well as the intensity differences of the component stars, but other processing algorithms more sophisticated than simple autocorrelation methods are required to extract this information. Such methods certainly exist, and a major emphasis of the CHARA program is to develop an image-reconstruction algorithm that efficiently and reliably permits the determination of the photometric properties of the components at separations down to the diffraction-limited cutoff. Examples of first results for *speckle photometry*, as we call such methods to distinguish them from the primarily astrometric applications of *speckle interferometry*, can be found in new studies of Capella (Bagnuolo and Sowell 1988) and the Hyades binary 70 Tauri = Finsen 342 (McAlister *et al.* 1988). In Table II, we adopt quadrants consistent with micrometer measures for known visual binaries, but we arbitrarily adopt $\theta < 180°$ for objects for which true quadrant determinations are not available. The exception to this rule is for those objects that have been first resolved by speckle interferometry and have shown motion since their first measurement requiring a value of $\theta > 180°$.

The 1550 measurements of 1006 systems in Table II combine with all previous measurements from this program to give a total of 7252 speckle measurements of binary stars resulting from the GSU speckle program as carried out at Kitt Peak National Observatory. In the *Second Catalog of Interferometric Measurements of Binary Stars* (McAlister and Hartkopf 1988) there are 8976 measurements from all interferometry groups known to the authors as of July 1988.

Many stars first resolved earlier in our program, the "McA" and "CHARA" stars, have been confirmed as binaries in the present series of measurements. Six McA stars (nos. 13, 17, 31, 39, 50, and 59) that had not been previously confirmed by us and 50 CHARA stars are measured here following their initial resolutions. While some of these systems have shown little orbital motion during the years following their first resolution, others are exhibiting very rapid motion. Such objects include CHARA 18 = HR 1458 (88 Tau), with 100° of position-angle change in 2.4 yr, and CHARA 26 = HR 2837 (61 Gem), with 108° of motion in 4.2 yr.

The mean angular separation of the observations in Table

TABLE II. Binary star speckle measurements.

HR 9097	CHARA 121				225094	00034+6339
		1986.8967	34°.4	0″.196		
ADS 30	CHARA 122 Aa				225218	00046+4206
		1986.8967	94.9	0.110		
ADS 32	STF 3056 AB				225220	00046+3416
		1987.7595	143.6	0.718		
ADS 61	STF 3062 AB				123	00062+5826
		1987.7595	303.6	1.448		
ADS 102	STF 2				431	00091+7943
		1987.7596	22.7	0.672		
+18°0003	Cou 247				489	00095+1907
		1987.7542	356.0	0.419		
ADS 124	Bu 253				570	00104+5831
		1987.7595	35.0	0.511		
ADS 143	STF 7				709	00116+5558
		1987.7595	211.5	1.331		
ADS 147	Bu 255				744	00119+2825
		1986.8940	75.1	0.506		
		1987.7595	75.2	0.519		
ADS 148	CHARA 1 Aa				761	00122+5337
		1987.7543	59.8	0.071		
		1987.7622	61.5	0.066		
ADS 161	STT 2 AB				895	00134+2659
		1986.8966	184.5	0.286		
ADS 197	A 1256 AB				1082	00152+4406
		1986.8859	68.8	0.105		
ADS 207	STF 13				1141	00163+7657
		1987.7596	56.5	0.913		
HR 63	CHARA 123				1280	00171+3841
		1986.8969	141.6	0.057		
ADS 238	A 1803 AB				1317	00173+0852
		1986.8859	142.6	0.088		
ADS 243	A 803				1360	00182+7256
		1986.8859	280.6	0.201		
		1987.7596	283.0	0.204		
ADS 281	Bu 1015				1634	00206+1219
		1987.7542	78.5	0.340		
ADS 293	STT 6 AB				1658	00214+6700
		1987.7596	154.8	0.561		
ADS 295	Cou 347 Aa				1688	00214+2744
		1987.7595	57.8	0.434		
ADS 328	Hu 506				1976	00243+5201
		1986.8859	48.5	0.168		
ADS 332	A 908				236401	00245+5632
		1987.7595	239.7	0.421		
ADS 382	A 1504 AB				2471	00287+3718
		1987.7595	37.6	0.544		
ADS 397	A 649				2549	00298+6905
		1987.7596	319.1	0.428		
ADS 416	Bu 394				2675	00308+4732
		1986.8859	303.2	0.152		
		1987.7595	309.4	0.111		
ADS 434	STT 12				2772	00318+5432
		1986.8940	187.5	0.468		
		1987.7595	188.2	0.464		
+26°0072	Cou 547				2854	00320+2740
		1986.8859	204.8	0.070		
ADS 450	A 111 AB				2880	00321−0511
		1987.7542	138.8	0.171		
ADS 463	Ho 3				2993	00335+4006
		1987.7543	119.8	0.262		
+29°0099	Cou 654				—	00345+3015
		1986.8859	213.9	0.235		
ADS 490	Ho 212 AB				3196	00352−0336
		1985.8401	292.0	0.250		
		1986.8859	331.5	0.118		
		1987.7542	7.9	0.149		
ADS 493	STT 15				3210	00358+4901
		1986.8859	318.4	0.220		
		1987.7595	319.5	0.217		
ADS 504	A 914				3304	00366+5608
		1987.7595	31.3	0.447		
ADS 559	Bu 257				3700	00402+4715
		1987.7595	247.3	0.644		
+35°0117	Cou 1051				3742	00405+3627
		1987.7595	81.0	0.442		
ADS 597	A 2205				—	00429+2047
		1987.7622	207.8	0.247		
+61°0159	Mlr 26				4116	00444+6210
		1987.7595	48.2	0.210		
ADS 684	Bu 232 AB				4777	00504+5038
		1986.8887	240.9	0.848		
		1987.7570	241.5	0.850		
ADS 701	A 1808				4934	00516+2238
		1986.8860	173.8	0.107		
		1987.7623	177.3	0.113		
ADS 732	A 2307				5143	00532+0406
		1987.7596	45.3	0.325		
+42°0196	Cou 1654				5178	00542+4318
		1986.8860	103.1	0.159		
		1987.7543	104.6	0.160		
ADS 746	STT 20 AB				5267	00546+1912
		1986.8940	208.8	0.443		
		1987.7596	209.0	0.472		
ADS 749	Hu 802				5259	00549+4924
		1986.8887	215.7	0.358		
		1987.7543	216.4	0.360		
ADS 755	STF 73 AB				5286	00550+2338
		1986.8887	277.2	0.685		
		1987.7544	280.1	0.692		
ADS 768	Bu 500				5316	00554+3040
		1986.8887	299.0	0.510		
		1987.7544	299.7	0.500		
ADS 777	Hu 1207				5398	00561+3352
		1987.7543	184.7	0.329		
ADS 773	A 1259				232319	00561+5406
		1987.7596	91.0	0.123		
ADS 784	Bu 1099 AB				5408	00568+6022
		1986.8860	323.0	0.244		
		1987.7570	325.8	0.249		
ADS 795	Hld 4				5502	00576+5424
		1987.7596	227.5	0.125		
ADS 805	Bu 302				5641	00583+2124
		1986.8887	165.7	0.427		
		1987.7596	167.2	0.420		
ADS 819	A 1902				5781	00593−0040
		1987.7596	182.8	0.319		
+40°0199	Cou 1505				5720	00594+4057
		1986.8860	136.6	0.206		
ADS 832	A 926				5851	01011+6021
		1987.7570	325.2	0.379		
ADS 828	Bu 867				5988	01014+1155
		1987.7596	6.7	0.390		
+34°0164	Cou 854				5955	01014+3535
		1986.8860	0.7	0.132		
		1987.7596	354.0	0.131		
ADS 836	A 2901				5839	01015+6921
		1986.8887	53.4	0.411		
		1987.7570	53.9	0.414		
ADS 854	A 2003				6094	01023+0552
		1987.7596	308.4	0.178		
ADS 859	Bu 1161				6084	01029+5148
		1986.8887	5.0	0.366		
		1987.7543	5.3	0.368		
ADS 862	STT 21				6114	01030+4723
		1987.7596	174.5	1.035		
ADS 871	Hu 517				—	01037+5026
		1986.8887	26.0	0.564		
		1987.7543	26.7	0.568		
ADS 873	Ho 213				6264	01039+3528
		1987.7543	99.5	0.291		
ADS 884	A 2310				6387	01048+0135
		1987.7596	325.1	0.290		
ADS 883	A 1515				—	01049+3649
		1986.8860	288.6	0.242		
		1987.7543	288.6	0.246		
ADS 916	A 931				6553	01070+4744
		1986.8887	90.3	0.074		
		1987.7623	95.0	0.073		
ADS 918	A 1516 AB				6586	01071+3539
		1986.8914	68.6	0.144		
		1987.7596	75.7	0.140		
		1987.7623	75.3	0.141		

TABLE II. (continued)

ADS 936	AC 13 AB			6757		01088+4512
		1986.8914	262.9		0.601	
		1987.7543	263.1		0.590	
ADS 940	STT 515			6811		01093+4715
		1986.8915	133.5		0.486	
		1987.7543	133.4		0.487	
ADS 955	Bu 303			6886		01096+2348
		1986.8914	290.8		0.657	
		1987.7544	291.0		0.654	
ADS 963	Bu 235 Aa			6918		01106+5101
		1987.7570	126.9		0.982	
ADS 993	A 1260			7255		01131+2942
		1987.7568	45.5		0.225	
ADS 1005	Hu 803			——		01151+3416
		1987.7570	206.3		0.849	
ADS 1039	Hu 520			7695		01178+4946
		1986.8915	164.6		0.314	
		1987.7570	165.4		0.315	
ADS 1040	STF 102 AB			7710		01178+4901
		1986.8915	278.5		0.489	
		1987.7570	278.9		0.490	
ADS 1045	A 937			7759		01181+4707
		1987.7570	218.4		0.292	
+32°0229	Cou 663			7854		01187+3245
		1986.8914	174.9		0.323	
		1987.7570	174.4		0.323	
ADS 1081	STF 113 A,BC			8036		01198−0029
		1987.7568	16.4		1.604	
ADS 1081	Fin 337 BC			8036		01198−0029
		1987.7568	267.0		0.114	
ADS 1105	STF 115 AB			8272		01233+5808
		1986.8861	303.4		0.090	
		1987.7544	296.9		0.073	
		1987.7625	295.4		0.081	
ADS 1123	Bu 1163			8556		01243−0655
		1986.8887	205.4		0.219	
		1987.7623	201.8		0.151	
+26°0235	Cou 666			——		01258+2733
		1986.8914	154.5		0.314	
		1987.7568	154.3		0.331	
ADS 1183	A 1910 AB			9071		01296+2250
		1986.8887	298.6		0.057	
		1987.7625	287.3		0.069	
+45°0359	Cou 1659			9031		01298+4547
		1987.7570	24.1		0.296	
+67°0131	CHARA 3			9015		01308+6722
		1986.8861	320.5		0.205	
HR 439	McA 3			9352		01334+5820
		1986.8861	115.5		0.124	
		1987.7544	115.6		0.119	
		1987.7625	112.9		0.109	
ADS 1224	A 1912 AB			9532		01342+3611
		1987.7570	1.5		0.199	
		1987.7625	1.1		0.199	
ADS 1263	A 817			9841		01371+4843
		1986.8915	28.5		0.476	
		1987.7570	29.5		0.477	
+39°0367	Cou 1214			——		01373+4015
		1987.7570	175.9		0.310	
HR 466	Kui 7			10009		01376−0924
		1986.8887	354.6		0.120	
		1987.7623	349.1		0.126	
ADS 1286	A 1266			10031		01392+5436
		1986.8915	235.2		0.221	
		1987.7570	235.9		0.214	
ADS 1309	A 1267			10146		01405+5457
		1986.8861	2.9		0.273	
		1987.7570	2.6		0.274	
ADS 1327	A 1268			10273		01417+5323
		1987.7625	265.0		0.126	
ADS 1341	B 2550 AB			——		01425+5000
		1987.7570	274.1		0.227	
ADS 1359	Bu 870			10543		01443+5732
		1987.7571	359.5		0.861	
ADS 1375	A 2322			——		01449+1951
		1987.7625	121.8		0.087	
+28°0295	[illegible]			——		01465+2936
		19[illegible]	69.9		0.272	
ADS 1410	[illegible] 1523			——		01472+4212
		1986.8887	64.1		0.399	
		1987.7571	64.9		0.402	
ADS 1438	STF 162 AB			11031		01492+4754
		1986.8942	202.5		1.993	
ADS 1438	CHARA 4 Aa			11031		01492+4754
		1986.8887	24.9		0.151	
		1987.7571	29.9		0.150	
ADS 1437	A 950 AB			236885		01495+5645
		1987.7625	226.9		0.163	
+25°0311	Cou 452			11245		01510+2551
		1986.8888	179.8		0.294	
		1987.7572	180.1		0.292	
ADS 1461	A 951			11126		01512+6021
		1987.7571	218.2		0.445	
ADS 1473	Ho 311			11284		01512+2439
		1987.7625	312.0		0.097	
ADS 1509	A 953			11472		01547+5955
		1987.7571	66.8		0.800	
ADS 1522	STF 183 AB			11671		01551+2847
		1986.8888	170.3		0.303	
		1987.7572	169.0		0.306	
ADS 1538	STF 186			11803		01558+0151
		1987.7572	57.6		1.217	
		1987.7651	57.2		1.212	
ADS 1537	A 1524 AB			11748		01563+4251
		1986.8887	235.5		0.344	
		1987.7571	238.0		0.350	
ADS 1548	A 819 AB			11849		01570+3101
		1986.8888	203.5		0.331	
		1987.7572	205.7		0.319	
ADS 1549	A 818			11826		01573+4812
		1987.7571	206.1		0.308	
ADS 1554	A 1526			11869		01576+4433
		1987.7625	252.8		0.120	
+40°0426	Cou 1510			——		02016+4107
		1986.8888	130.2		0.377	
		1987.7571	131.4		0.360	
ADS 1598	Bu 513 AB			12111		02019+7054
		1986.8942	222.6		0.787	
ADS 1615	STF 202			12446		02020+0246
		1986.8942	280.2		1.900	
ADS 1613	A 1813 AB			12376		02022+3643
		1986.8888	13.2		0.142	
		1987.7625	28.0		0.097	
+08°0316	McA 4			12483		02026+0905
		1986.8888	141.2		0.225	
		1987.7572	142.0		0.229	
ADS 1630	STT 38 BC			12534		02035+4223
		1986.8887	107.7		0.531	
		1987.7571	108.1		0.574	
+69°0129	Mlr 375			12300		02038+7013
		1987.7571	206.6		0.232	
+38°0401	Cou 1365			12592		02043+3924
		1986.8888	129.7		0.196	
		1987.7625	129.7		0.194	
+29°0357	Cou 455			——		02055+3018
		1986.8888	97.2		0.456	
		1987.7571	98.0		0.449	
+34°0379	Cou 1067			13102		02090+3541
		1986.8888	13.1		0.118	
		1987.7625	16.0		0.131	
ADS 1680	A 2325			——		02097+0048
		1987.7572	119.3		0.255	
+43°0436	Cou 1667			——		02107+4426
		1987.7625	77.6		0.154	
ADS 1701	Ho 497			13496		02128+3722
		1986.8888	83.6		0.541	
		1987.7571	82.9		0.529	
HR 643	CHARA 5			13520		02132+4414
		1987.7571	186.6		0.221	
HR 640	McA 6			13474		02145+6631
		1986.8889	75.7		0.054	

TABLE II. (continued)

HR 667	Cou 79				13872	02157+2503
		1986.8888	64.9	0.086		
		1987.7626	54.6	0.147		
+40°0469	Cou 1669				13844	02160+4046
		1986.8889	173.0	0.223		
		1987.7626	171.6	0.235		
+40°0476	Cou 1670				14137	02183+4120
		1986.8916	46.3	0.150		
		1987.7626	48.9	0.146		
ADS 1763	Egg 2 Aa				14189	02186+4017
		1986.8888	112.8	0.136		
		1987.7626	120.3	0.148		
+24°0344	Cou 357				14918	02250+2529
		1986.8888	135.9	0.281		
ADS 1833	STF 257				14817	02257+6133
		1986.8943	49.7	0.346		
		1987.7653	51.8	0.349		
+44°0500	Cou 2011				15174	02279+4523
		1986.8942	68.3	0.344		
HR 719	Kui 8				15328	02280+0158
		1986.8915	33.6	0.614		
ADS 1860	CHARA 6 Ap				15089	02290+6724
		1987.7651	150.1	0.347		
ADS 1938	STT 42 AB				15703	02333+5218
		1986.8916	285.8	0.135		
		1987.7627	286.8	0.130		
+79°0075	Mlr 449				15416	02361+7944
		1987.7653	196.0	0.278		
+39°0577	Bnz				16097	02363+4012
		1986.8888	71.5	0.310		
HR 763	McA 7				16234	02366+1226
		1986.8888	169.6	0.051		
		1987.7626	131.1	0.065		
ADS 1992	A 1278				16283	02383+4604
		1986.8916	152.5	0.127		
		1987.7626	149.1	0.129		
ADS 1985	STF 278				16096	02389+6918
		1986.8943	36.7	0.495		
ADS 2010	A 2023				16486	02393+2552
		1986.8888	226.6	0.593		
HR 781	Fin 312				16620	02396−1153
		1986.8888	289.6	0.126		
		1987.7626	12.7	0.103		
ADS 2028	A 1928				16619	02398+0009
		1986.8915	269.2	0.158		
HR 788	McA 8				16739	02422+4012
		1986.8862	69.4	0.042		
		1986.8888	69.1	0.041		
		1987.7626	79.8	0.047		
HR 793	μ Ari				16811	02424+2000
		1986.8888	253.4	0.042		
		1987.7626	266.8	0.052		
+47°0717	Cou 2013				17670	02520+4831
		1986.8917	96.6	0.208		
		1987.7653	92.4	0.206		
ADS 2185	A 2906 AB				17743	02529+5300
		1986.8916	134.2	0.169		
		1987.7653	134.4	0.180		
ADS 2200	Bu 524 AB				17904	02537+3820
		1986.8917	273.7	0.189		
ADS 2246	Bu 1173 AB				18442	02586+2408
		1987.7653	87.8	0.228		
ADS 2253	Bu 525				18484	02589+2137
		1986.8943	259.0	0.512		
ADS 2257	STF 333 AB				18519	02592+2120
		1986.8943	207.5	1.459		
ADS 2271	A 1529				18549	03006+4753
		1987.7653	163.4	0.209		
ADS 2276	A 827				18424	03024+7236
		1987.7653	247.1	0.230		
HR 915	γ Per				18925	03048+5330
		1986.8861	63.9	0.221		
		1987.7653	64.3	0.194		
ADS 2336	STF 346 AB				19134	03055+2515
		1986.8943	63.9	0.260		
HR 936	β Per Aa				19356	03082+4057
		1986.8861	133.7	0.104		
		1986.8917	133.7	0.099		
+17°0515	Cou 359				—	03143+1821
		1986.8889	170.6	0.165		
ADS 2429	Hu 1055				—	03151+1618
		1986.8889	84.9	0.206		
ADS 2436	STT 52 AB				20104	03175+6539
		1986.8945	69.2	0.465		
		1987.7653	69.4	0.465		
+28°0532	CHARA 9				21242	03266+2843
		1986.8889	62.4	0.438		
		1987.7651	62.3	0.438		
HR 1036	CHARA 10				21335	03271+1845
		1986.8862	127.4	0.075		
ADS 2546	Cou 260				21437	03280+2028
		1986.8889	22.3	0.232		
		1987.7572	22.5	0.233		
ADS 2538	A 980				21203	03283+6015
		1986.8944	11.8	0.271		
		1987.7545	10.2	0.280		
+34°0678	Cou 1079 AB				278801	03333+3522
		1987.7572	36.8	0.313		
+57°0730	CHARA 117				21794	03337+5752
		1986.8862	180.5	0.096		
		1987.7654	201.0	0.097		
ADS 2616	STF 412 AB				22091	03345+2428
		1986.8889	1.8	0.625		
		1987.7545	1.9	0.630		
ADS 2627	Cou 688 Aa				22181	03353+2651
		1986.8889	194.0	0.462		
		1987.7545	197.1	0.479		
ADS 2628	Bu 533				22195	03356+3141
		1986.8943	41.6	1.095		
		1987.7545	42.6	1.095		
ADS 2630	A 1535				22193	03361+4221
		1987.7545	321.0	0.645		
+44°0747	Cou 1862				22209	03364+4518
		1987.7545	16.1	0.308		
+31°0637	Cou 691				—	03423+3141
		1987.7654	111.9	0.087		
ADS 2745	A 1828				23403	03450+0504
		1987.7572	13.4	0.154		
+23°0512	Cou 560				23387	03456+2420
		1986.8889	0.2	0.243		
		1987.7572	0.4	0.238		
		1987.7628	0.9	0.239		
+24°0562	CHARA 124				23568	03470+2431
		1987.7628	4.1	0.208		
ADS 2776	Bu 1184				23743	03483+2223
		1986.8889	270.2	0.503		
		1987.7544	270.5	0.503		
ADS 2765	STT 62				23406	03488+6445
		1987.7546	319.5	0.363		
HR 1180	CHARA 125				23862	03492+2408
		1987.7628	54.9	0.217		
HR 1176	CHARA 126				23838	03501+4458
		1986.8862	52.0	0.031		
ADS 2799	STT 65				23985	03504+2536
		1986.8945	209.3	0.434		
		1987.7545	210.1	0.407		
ADS 2811	A 1830				24104	03513+2621
		1986.8862	194.1	0.118		
		1987.7654	194.9	0.145		
HR 1199	Kui 15				24263	03519+0633
		1986.8890	207.7	0.682		
		1986.8945	207.6	0.679		
		1987.7546	207.8	0.683		
+27°0582	Cou 696				282993	03520+2801
		1986.8862	53.4	0.221		
		1987.7572	52.0	0.219		
ADS 2815	STT 66				24117	03521+4048
		1987.7545	143.0	0.957		
ADS 2911	Hu 27				25034	03591+0048
		1987.7546	302.3	0.305		

TABLE II. (continued)

ADS 2928	A 1937		25248		04008+0505
	1987.7599	202.5		0.155	
+35°0785	Cou 1081		279230		04009+3618
	1986.8862	21.2		0.187	
	1987.7599	23.2		0.185	
+15°0571	Hei 34		285332		04022+1532
	1987.7599	23.7		0.360	
ADS 2965	McA 13 Aa		25555		04044+2406
	1986.8862	6.0		0.036	
	1987.7655	339.2		0.036	
+19°0662	CHARA 13		25811		04063+1952
	1986.8862	59.9		0.074	
	1986.8890	60.6		0.079	
	1987.7655	56.9		0.074	
+39°0930	Cou 1394		276063		04070+3934
	1987.7545	119.4		0.247	
+45°0876	Cou 2025		25891		04081+4535
	1986.8862	331.8		0.287	
	1987.7545	332.7		0.278	
+33°0795	Cou 1082		25976		04081+3407
	1986.8862	59.5		0.288	
	1987.7546	59.4		0.288	
ADS 3007	A 998		25987		04089+4614
	1986.8862	258.1		0.162	
	1987.7599	255.2		0.159	
ADS 3032	A 469		26294		04094−0756
	1986.8889	112.5		0.166	
+42°0904	Cou 1702		26139		04100+4235
	1986.8862	126.6		0.167	
	1987.7599	128.1		0.169	
ADS 2963	STF 460		25007		04101+8042
	1986.8945	118.4		0.777	
	1987.7545	119.7		0.772	
+31°0718	Cou 880		26385		04117+3133
	1987.7546	43.9		0.718	
+23°0635	CHARA 14		284163		04119+2338
	1987.7546	96.0		0.113	
ADS 3053	STT 74		26547		04123+0939
	1986.8864	273.7		0.225	
	1987.7546	274.4		0.210	
ADS 3064	A 1938		26690		04136+0743
	1985.8406	235.7		0.062	
	1986.8864	290.8		0.110	
	1986.8890	290.3		0.108	
	1987.7655	308.4		0.146	
	1988.2600	315.8		0.153	
ADS 3098	STF 511		26839		04179+5847
	1986.8890	101.5		0.488	
	1987.7545	100.5		0.488	
HR 1331	McA 14 Aa		27176		04185+2135
	1986.8865	111.3		0.089	
	1986.8890	112.5		0.086	
	1987.7655	57.4		0.078	
ADS 3105	STT 75		26882		04186+6029
	1986.8890	178.9		0.414	
	1987.7545	181.3		0.415	
ADS 3135	STT 79		27383		04187+1632
	1986.8864	204.0		0.186	
	1987.7546	219.3		0.206	
	1988.2600	225.6		0.217	
ADS 3169	STT 82 AB		27691		04228+1504
	1987.7600	352.6		1.358	
HR 1376	CHARA 16		27742		04236+2059
	1986.8865	1.0		0.233	
ADS 3172	STT 80		27650		04236+4226
	1986.8890	156.6		0.356	
	1987.7548	156.5		0.355	
ADS 3182	Hu 304		27820		04239+0928
	1986.8890	83.5		0.142	
ADS 3191	Bu 1235		27832		04245+2245
	1987.7600	60.5		0.316	
ADS 3184	A 834 AB		27696		04254+5623
	1986.8890	219.4		0.638	
	1987.7601	220.0		0.642	
ADS 3210	Bu 1185		27989		04256+1852
	1986.8864	216.9		0.128	
	1987.7600	212.6		0.167	
	1988.2600	209.1		0.175	
HR 1391	Fin 342 Aa		27991		04256+1557
	1986.8864	89.7		0.094	
	1986.8890	88.3		0.096	
	1987.7655	65.4		0.087	
ADS 3211	Hu 609		27961		04262+3443
	1987.7600	2.5		0.188	
ADS 3228	Bu 1186		28217		04275+1113
	1986.8890	124.3		0.188	
	1987.7600	122.5		0.181	
HR 1411	McA 15		28307		04286+1557
	1986.8864	354.7		0.221	
	1986.8890	354.7		0.221	
	1987.2689	353.3		0.204	
	1987.7600	352.2		0.203	
ADS 3227	Bu 745		28062		04287+5355
	1986.8890	110.4		0.403	
	1987.7600	111.1		0.404	
ADS 3248	Hu 1080		28363		04290+1610
	1986.8890	258.8		0.458	
	1987.7546	258.9		0.455	
	1988.2600	258.3		0.454	
ADS 3246	A 1713		——		04294+4407
	1986.8890	205.3		0.430	
	1987.7600	205.9		0.435	
+17°0735	Cou 567		28436		04298+1741
	1986.8917	19.4		0.151	
	1987.7600	19.9		0.143	
ADS 3264	STF 554		28455		04301+1538
	1987.7600	18.8		1.664	
+14°0721	CHARA 17		285931		04340+1510
	1987.7600	60.4		0.169	
ADS 3300	A 1714		28803		04344+4241
	1987.7600	252.8		0.393	
ADS 3317	CHARA 18 Aa		29140		04357+1010
	1986.8865	66.2		0.089	
	1987.7655	102.5		0.113	
	1988.2601	116.8		0.136	
ADS 3326	A 1840 AB		——		04361+0813
	1986.8918	101.2		0.166	
	1987.7601	98.5		0.163	
ADS 3329	STT 86		29193		04366+1945
	1986.8917	13.5		0.471	
	1987.7574	13.3		0.469	
+30°0697	Cou 883		282310		04378+3116
	1987.7573	50.0		0.264	
ADS 3332	A 1010		29180		04378+4442
	1986.8892	341.3		0.507	
	1987.7573	341.5		0.511	
ADS 3360	A 2035		286952		04387+1011
	1987.7574	111.4		0.228	
ADS 3371	Bu 1044		29562		04398+1632
	1987.7574	210.8		0.651	
ADS 3358	Bu 1295 AB		29316		04399+5329
	1987.7601	91.1		0.073	
ADS 3358	STF 566 AC		29316		04399+5329
	1987.7601	219.5		0.719	
ADS 3370	Hu 442		29538		04400+2301
	1987.7574	56.8		0.145	
ADS 3387	A 2353		29727		04416+1643
	1986.8917	162.6		0.159	
	1987.7574	162.5		0.155	
HR 1497	McA 16		29763		04422+2257
	1986.8865	332.6		0.197	
	1987.2717	345.8		0.215	
	1987.7573	325.9		0.196	
	1988.2601	323.4		0.194	
ADS 3389	A 1014		29599		04430+5712
	1987.7573	324.9		0.280	
ADS 3391	A 1013		29606		04432+5032
	1986.8892	245.6		0.128	
	1987.7601	251.7		0.144	
+39°1054	Cou 1524		29911		04445+3953
	1987.7601	199.5		0.105	

TABLE II. (continued)

+42°1045	Cou 2031				30090	04465+4220
		1986.8892	321.0	0.094		
ADS 3447	A 1545 AB				30245	04477+4014
		1987.7573	95.7	0.421		
+43°1060	Cou 2033				30255	04480+4339
		1986.8892	136.3	0.211		
		1987.7573	136.3	0.206		
ADS 3465	A 2621				30636	04496+0213
		1986.8918	81.6	0.151		
		1987.7601	81.9	0.149		
+14°0770	CHARA 20				30712	04506+1505
		1988.2601	120.5	0.085		
ADS 3475	Bu 883 AB				30810	04512+1104
		1986.8918	142.7	0.137		
		1987.7574	182.9	0.107		
ADS 3483	Bu 552 AB				30869	04518+1339
		1986.8837	150.2	0.373		
		1987.7601	162.0	0.401		
		1988.2600	166.7	0.403		
ADS 3486	Hu 819				30884	04529+3548
		1987.7573	278.8	0.441		
ADS 3501	A 1843 AB				31033	04536+2522
		1987.7573	299.0	0.519		
ADS 3501	CHARA 127 Aa				31033	04536+2522
		1987.7573	109.9	0.075		
ADS 3490	Hu 818				30807	04539+5603
		1987.7573	72.6	0.448		
HR 1569	McA 17				31283	04548+1125
		1987.7574	309.5	0.207		
ADS 3522	A 1019 AB				31356	04551−0033
		1987.7601	122.9	0.161		
ADS 3542	STT 91				31466	04562+0311
		1987.7601	227.5	0.408		
ADS 3536	D 5				31278	04573+5045
		1987.7573	227.9	0.483		
ADS 3558	A 2624				31622	04573+0100
		1987.7601	305.9	0.330		
+26°0767	Cou 758				284006	04581+2618
		1987.7573	143.7	0.375		
+40°1114	Cou 1717				31519	04585+4047
		1987.7573	118.2	0.252		
ADS 3573	A 1303				31578	04599+5328
		1987.7573	309.6	0.198		
+69°0288	Mlr 399 AB				31264	05001+6958
		1987.7573	169.2	0.266		
+41°1027	Cou 1866				31759	05004+4158
		1987.7573	70.4	0.308		
+21°0754	Cou 154 AB				32481	05044+2129
		1986.8837	307.2	0.262		
ADS 3659	A 1023				32416	05054+4655
		1986.8837	60.7	0.332		
ADS 3728	A 2636				33235	05089+0313
		1987.7601	158.3	0.282		
ADS 3734	STF 644				33203	05104+3718
		1986.8837	221.4	1.630		
ADS 3755	Bu 885				33545	05109−0146
		1986.8838	195.8	0.612		
ADS 3767	Hu 33				33647	05117+0031
		1986.8892	4.6	0.111		
ADS 3799	STT 517 AB				33883	05134+0158
		1986.8838	235.3	0.552		
		1986.8892	235.4	0.549		
		1987.7601	235.8	0.552		
+36°1049	Pop 140				33749	05140+3655
		1986.8837	158.8	0.266		
HR 1708	α Aur Aa				34029	05167+4601
		1986.8892	22.2	0.051		
		1987.2717	79.4	0.037		
		1987.7656	355.0	0.044		
		1988.2545	259.8	0.048		
+30°1272	Cou 2037				34807	05219+3934
		1986.8837	141.4	0.300		
ADS 4002	McA 18 Aab,c				35411	05244−0224
		1986.8892	126.9	0.060		
		1988.2546	116.0	0.052		
ADS 4020	A 848				35548	05255−0033
		1986.8892	161.6	0.222		
ADS 4032	Ho 226 AB				35586	05270+2737
		1986.8838	261.3	0.763		
ADS 4038	McA 19 Aa				35671	05271+1758
		1986.8893	281.6	0.060		
		1987.2717	274.3	0.069		
		1988.2490	275.7	0.083		
ADS 4078	Da 6				36058	05290−0318
		1988.2546	211.1	0.137		
-01°0918	Rst 4781				36219	05301−0145
		1986.8838	199.0	0.403		
		1986.8892	199.1	0.405		
ADS 4115	STF 728				36267	05307+0556
		1986.8838	47.8	1.031		
ADS 4134	Hei 42 Aa				36486	05320−0018
		1986.8892	139.7	0.253		
		1988.2545	139.7	0.261		
HR 1891	Fin 345				37016	05353−0425
		1986.8838	92.8	0.362		
+20°1009	Cou 270				36880	05357+2054
		1986.8918	45.0	0.028		
ADS 4208	STF 749 AB				37098	05372+2656
		1986.8918	325.6	1.122		
+43°1316	CHARA 21				36948	05373+4404
		1986.8893	59.4	0.127		
		1988.2601	59.2	0.124		
HR 1853	Mlr 314				36496	05373+6642
		1986.8837	141.8	0.107		
ADS 4203	A 1562				36928	05373+4339
		1986.8893	350.0	0.403		
ADS 4229	Bu 1240 AB				37269	05386+3030
		1986.8893	24.4	0.112		
		1988.2490	18.2	0.122		
		1988.2545	18.3	0.122		
ADS 4241	Bu 1032 AB				37468	05387−0236
		1986.8918	142.3	0.253		
		1988.2545	140.6	0.253		
ADS 4247	A 2709				37477	05394+1150
		1986.8918	56.8	0.270		
ADS 4236	A 1564				37265	05394+4343
		1986.8893	138.1	0.154		
ADS 4243	STT 112				37384	05398+3758
		1986.8858	51.9	0.857		
ADS 4249	Hu 825				37405	05400+3601
		1986.8838	345.9	0.394		
ADS 4266	Bu 1007				37711	05411+1632
		1986.8838	239.8	0.334		
		1988.2545	240.5	0.327		
ADS 4279	Bu 1052				37904	05417−0254
		1986.8838	17.2	0.399		
ADS 4277	A 2110 AB				37801	05421+2135
		1986.8918	122.3	0.457		
ADS 4301	A 2436				38037	05435+1642
		1986.8918	134.6	0.235		
+29°0972	Cou 895				246742	05439+2937
		1986.8893	54.2	0.155		
ADS 4323	STT 118 AB				38182	05446+1503
		1986.8838	119.2	0.470		
ADS 4324	A 496				38161	05449+2620
		1986.8893	6.2	0.281		
+28°0871	Cou 762				38153	05450+2812
		1986.8893	60.5	0.181		
ADS 4373	Hu 39				38493	05472+2153
		1986.8918	48.1	0.197		
ADS 4390	STF 795				38710	05480+0627
		1986.8918	315.2	1.187		
ADS 4392	STT 118 AB				38670	05484+2052
		1986.8918	316.8	0.205		
ADS 4376	STF 3115				38284	05491+6246
		1986.8838	340.4	0.871		
ADS 4464	Cou 897 CD				39274	05528+2046
		1986.8893	230.7	0.225		
+29°1028	Cou 898				39303	05529+2907
		1986.8893	157.8	0.158		
+28°0933	Cou 900				39451	05539+2857
		1986.8893	83.2	0.168		
ADS 4505	STT 122				39697	05558+3656
		1986.8893	256.7	0.285		

TABLE II. (continued)

+24°1043	Cou 905		40152		05580+2437
	1986.8920	16.4		0.192	
ADS 4543	A 1725		——		05589+4510
	1986.8920	212.2		0.346	
ADS 4562	STT 124		40369		05509+1249
	1986.8920	297.7		0.513	
	1987.2744	298.4		0.508	
ADS 4575	A 2441		40427		05594+1344
	1986.8920	272.7		0.766	
ADS 4593	A 110		40628		06013+2027
	1986.8920	202.5		0.570	
ADS 4617	A 2715 AB		40932		06024+0939
	1986.8865	206.4		0.218	
	1987.2744	205.6		0.248	
	1988.2545	204.7		0.316	
ADS 4623	J 60		40982		06027+0801
	1986.8921	233.5		0.561	
HR 2130	McA 24		41040		06034+1942
	1986.8865	84.7		0.053	
	1988.2491	77.4		0.056	
HR 2134	Kui 23 AB		41116		06041+2316
	1986.8865	168.1		0.252	
	1987.2717	171.8		0.260	
	1988.2491	179.0		0.270	
ADS 4660	A 1951		41379		06052+0708
	1986.8921	43.6		0.456	
	1987.2744	43.7		0.445	
ADS 4603	STT 121		40225		06053+7400
	1986.8918	238.9		0.260	
ADS 4681	A 2444		41527		06065+1832
	1986.8920	180.3		0.284	
ADS 4687	STF 840 BC		41580		06066+1046
	1986.8921	134.3		0.425	
+18°1095	Cou 471		41658		06073+1848
	1986.8920	167.1		0.311	
+26°1082	McA 25		41600		06074+2640
	1986.8865	218.4		0.068	
	1987.2717	224.3		0.068	
	1988.2491	228.7		0.070	
ADS 4696	STT 130		41541		06078+4240
	1986.8920	200.1		0.418	
ADS 4752	A 2514		252561		06097+1630
	1986.8920	90.7		0.300	
ADS 4750	A 54 AB		42033		06098+2014
	1986.8920	336.1		0.569	
ADS 4768	Bu 1058		42216		06105+2300
	1986.8920	235.4		0.228	
ADS 4786	A 55 AB		42395		06117+2046
	1986.8920	269.0		0.424	
ADS 4788	Ku 701		42306		06120+3531
	1986.8920	241.5		0.183	
HR 2214	Kui 24		42954		06144+1754
	1986.8920	139.6		0.494	
	1987.2744	140.6		0.488	
ADS 4843	A 2044 AB		253926		06150+1649
	1986.8920	31.4		0.400	
HR 2236	Rst 5225		43358		06159+0110
	1986.8921	244.7		0.193	
	1987.2744	248.7		0.186	
ADS 4890	Fin 331 Aa		43525		06171+0957
	1986.8865	3.9		0.058	
	1987.2744	27.5		0.062	
	1988.2491	69.9		0.067	
HR 2273	CHARA 22		44112		06197−0749
	1988.2491	55.8		0.063	
ADS 4929	Bu 895 AB		43885		06200+2826
	1986.8565	130.5		0.254	
ADS 4951	A 2719		44109		06203+0744
	1986.8838	62.0		0.470	
ADS 4971	A 2667		44333		06214+0216
	1987.2745	184.2		0.286	
+25°1232	Cou 718		44211		06216+2500
	1986.8865	139.6		0.220	
ADS 4950	STF 881 AB		43812		06221+5922
	1986.8839	134.1		0.700	
	1987.2719	134.2		0.697	
ADS 4950	CHARA 128 Aa		43812		06221+5922
	1986.8839	109.5		0.187	
HR 2312	Fin 343		45050		06252+0130
	1987.2744	0.1		0.173	
+23°1346	CHARA 23		44926		06255+2327
	1986.8865	154.5		0.112	
	1987.2662	154.3		0.114	
	1988.2491	153.9		0.115	
HR 2304	McA 26		44927		06256+2320
	1986.8865	142.0		0.072	
	1987.2662	144.4		0.074	
	1988.2491	145.1		0.079	
+24°1276	Cou 914		45428		06283+2441
	1986.8865	119.6		0.219	
HR 2392	CHARA 129		46407		06328−1110
	1985.8381	54.3		0.161	
ADS 5218	A 506		46610		06357+2816
	1986.8865	33.5		0.250	
	1987.2662	34.4		0.250	
HR 2425	McA 27		47152		06383+2859
	1986.8865	323.0		0.151	
	1987.2662	322.1		0.163	
	1988.2491	318.3		0.171	
ADS 5280	STT 150		47193		06393+4200
	1986.8865	211.8		0.088	
ADS 5289	STT 152		47395		06395+2816
	1986.8838	34.9		0.887	
ADS 5296	STF 945		47412		06404+4058
	1986.8838	312.2		0.493	
	1987.2719	312.4		0.489	
ADS 5332	A 218		47812		06418+3041
	1986.8865	67.8		0.194	
+70°0410	Mlr 405		46979		06425+7035
	1988.2573	245.6		0.552	
ADS 5405	A 122		48591		06455+2922
	1986.8866	49.6		0.246	
ADS 5447	STT 156		49059		06474+1812
	1986.8839	233.5		0.397	
	1987.2745	233.2		0.397	
	1988.2548	231.3		0.386	
ADS 5455	STT 157		49294		06478+0020
	1986.8839	202.2		0.343	
HR 2521	Fin 322		49643		06492−0217
	1987.2744	52.9		0.158	
	1988.2546	50.4		0.153	
ADS 5466	A 2360		——		06494+4037
	1986.8866	273.5		0.130	
+35°1511	Cou 1738		49472		06502+3625
	1986.8866	110.3		0.107	
+24°1477	Cou 768		49622		06503+2419
	1986.8866	243.0		0.117	
+33°1424	Cou 1562		265119		06525+3248
	1986.8856	313.8		0.248	
ADS 5514	STF 963 AB		49618		06532+5920
	1986.8866	267.1		0.258	
	1987.2719	268.4		0.252	
	1988.2548	270.6		0.246	
HR 2541	Cou 1377		50037		06532+3827
	1986.8839	154.4		0.498	
	1987.2719	156.5		0.479	
+32°1447	Cou 1412		51023		06571+3217
	1986.8866	86.4		0.242	
ADS 5586	STT 159 AB		50522		06573+5825
	1986.8839	50.2		0.349	
	1987.2719	51.6		0.328	
	1988.2548	54.1		0.273	
	1988.2672	54.8		0.272	
ADS 5621	A 2459		266945		06577+1935
	1988.2574	279.8		0.359	
+02°1483	CHARA 25		51566		06580+0218
	1987.2717	30.8		0.947	
+24°1481	Cou 921		267067		06584+2443
	1986.8866	56.0		0.104	

TABLE II. (continued)

HR 2605	McA 28			51688		06595+2555
		1986.8866	52.4		0.060	
		1987.2719	56.2		0.069	
		1988.2491	57.1		0.055	
+31°1463	Cou 1241			267337		06598+3141
		1986.8866	308.9		0.154	
ADS 5660	A 2461 AB			51911		06598+1557
		1986.8839	327.6		0.319	
		1988.2548	328.4		0.312	
		1988.2574	327.7		0.316	
ADS 5689	STT 163 AB			52309		07011+1146
		1986.8866	64.9		0.120	
ADS 5724	A 1324 AB			—		07041+5627
		1988.2573	178.4		0.333	
+37°1645	McA 29			52823		07043+3734
		1986.8867	179.1		0.181	
		1988.2491	180.8		0.183	
ADS 5752	A 519			53299		07044−0303
		1988.2574	274.9		0.418	
+36°1567	Cou 2063			53816		07080+3552
		1986.8867	4.5		0.192	
		1986.8894	2.8		0.192	
+16°1395	Hei 125			54128		07083+1638
		1986.8866	220.0		0.217	
+20°1729	Cou 925			54985		07118+1953
		1986.8921	79.0		0.490	
		1988.2574	77.3		0.499	
ADS 5867	A 2847			55163		07121+0622
		1988.2574	130.1		0.418	
ADS 5918	Bu 1022			55726		07151+2553
		1986.8893	302.9		0.449	
		1988.2573	301.6		0.432	
ADS 5940	A 2853			56153		07164+1227
		1988.2574	320.8		0.480	
ADS 5949	A 2855			56361		07168+0059
		1988.2574	272.4		0.390	
+37°1696	Cou 1883			—		07173+3744
		1986.8894	59.4		0.648	
ADS 5952	A 2856			56444		07175+1324
		1988.2574	302.6		0.509	
+24°1600	Cou 585			56462		07181+2405
		1986.8893	155.0		0.396	
ADS 5975	Hu 619 AB			56627		07202+4820
		1986.8894	0.6		0.319	
ADS 5996	STF 1074 AB			57275		07205+0024
		1986.8921	168.6		0.666	
		1988.2574	169.5		0.671	
+14°1649	Hei 128			57675		07227+1417
		1986.8866	49.3		0.179	
HR 2837	CHARA 26			58579		07269+2015
		1986.8867	202.6		0.060	
		1988.2520	235.5		0.050	
ADS 6089	McA 30 Aa			58728		07277+2127
		1986.8867	166.8		0.103	
		1986.8893	167.1		0.104	
		1987.2689	163.3		0.094	
		1988.2520	100.2		0.089	
ADS 6114	A 2868			59151		07292+1253
		1986.8921	10.0		0.668	
ADS 6119	McA 31 Aa			59148		07298+2755
		1986.8867	198.5		0.041	
		1986.8894	197.6		0.039	
ADS 6138	A 2869			59473		07305+0743
		1986.8921	11.6		0.126	
ADS 6137	A 673 AB			59372		07309+3034
		1986.8894	350.6		0.388	
HR 2866	McA 32			60107		07336+1550
		1986.8895	91.1		0.169	
		1987.2745	91.1		0.166	
		1988.2491	93.2		0.151	
ADS 6185	STT 175 AB			60318		07352+3058
		1986.8894	328.2		0.212	
		1987.2690	328.7		0.214	
ADS 6200	A 2874			60634		07362+1815
		1986.8922	56.1		0.270	
+20°1855	Cou 381			—		07370+2025
		1986.8895	107.8		0.322	
+28°1427	Cou 1247			61034		07385+2819
		1986.8894	124.4		0.133	
ADS 6245	A 535			61344		07387−0459
		1987.2745	170.7		0.349	
ADS 6276	STT 177			61600		07417+3726
		1986.8921	162.7		0.411	
ADS 6347	Ho 247			62720		07462+2108
		1986.8921	233.7		0.408	
		1987.2745	234.3		0.408	
+19°1832	Cou 772			62947		07471+1847
		1986.8895	72.7		0.246	
-03°2065	Rst 4375			63263		07478−0332
		1986.8895	336.8		0.112	
		1987.2745	330.8		0.108	
ADS 6354	Hu 1247			62522		07479+6019
		1986.8894	261.4		0.236	
-19°2068	B 1077 AB			63395		07480−1924
		1987.2745	303.8		0.592	
ADS 6378	WRH 15 AB			63208		07486+2309
		1986.8895	47.3		0.277	
+20°1920	Cou 926			—		07506+1944
		1986.8895	256.3		0.293	
ADS 6405	A 2880			63709		07508+0317
		1986.8895	303.1		0.085	
		1987.2745	307.8		0.079	
ADS 6412	Bu 1195			63976		07513−0925
		1987.2745	90.9		0.179	
ADS 6420	Bu 101			64096		07518−1352
		1987.2745	103.1		0.365	
HR 3072	Fin 325			64235		07528−0526
		1987.2745	191.6		0.175	
+14°1778	Hei 55			—		07540+1346
		1986.8895	351.2		0.163	
ADS 6444	Cou 1111 Aa			64350		07545+2610
		1988.2574	165.9		0.512	
ADS 6443	A 675			64326		07546+3100
		1986.8894	157.4		0.193	
ADS 6445	A 1072			64123		07556+5831
		1986.8894	348.3		0.206	
+24°1805	Cou 929			64704		07561+2342
		1986.8895	150.7		0.147	
		1988.2520	159.0		0.163	
ADS 6483	STT 185			65123		07573+0108
		1986.8895	86.5		0.145	
		1987.2745	88.1		0.143	
+27°1521	Cou 1112			—		08001+2659
		1986.8894	97.2		0.265	
ADS 6511	A 2954 AB			65738		08005+0955
		1988.2576	344.0		0.707	
ADS 6526	A 1580			66094		08017−0836
		1986.8895	261.1		0.247	
		1987.2745	265.4		0.239	
ADS 6538	STT 186			66176		08033+2616
		1986.8839	73.2		0.946	
		1988.2574	74.1		0.967	
ADS 6549	STT 187			66299		08043+3302
		1986.8867	352.7		0.363	
		1987.2664	353.3		0.362	
		1988.2574	352.9		0.364	
ADS 6554	Bu 581 AB			66509		08043+1218
		1987.2664	279.5		0.551	
ADS 6578	A 1333			66610		08070+5407
		1986.8839	206.8		0.377	
		1986.8868	207.1		0.375	
		1987.2665	206.0		0.366	
ADS 6650	STF 1196 AB			68255		08122+1740
		1986.8839	213.3		0.602	
		1987.2664	209.2		0.594	
		1988.2576	197.9		0.588	
+29°1712	Cou 1114			69254		08126+2840
		1986.8867	225.7		0.209	
		1987.2664	223.6		0.196	

TABLE II. (continued)

ADS 6681	Hu 1123			68660		08148+3630
		1986.8867	156.7		0.430	
		1988.2574	157.8		0.416	
ADS 6733	A 2362			69580		08193+4052
		1988.2574	172.1		0.588	
HR 3269	Fin 346			70013		08199+0357
		1986.8922	68.2		0.275	
		1987.2664	69.7		0.271	
ADS 6762	STF 1216			70340		08214−0136
		1986.8839	282.2		0.524	
		1988.2576	283.5		0.518	
ADS 6776	Ho 525 AB			70492		08231+2001
		1986.8867	135.1		0.316	
ADS 6796	Hu 856			70803		08253+3723
		1986.8867	261.5		0.262	
		1987.2665	262.9		0.259	
ADS 6811	A 1746 BC			71153		08267+2433
		1986.8867	13.9		0.154	
ADS 6825	A 550			71499		08278−0425
		1986.8895	185.7		0.137	
ADS 6828	A 551 AB			71663		08285−0230
		1986.8895	79.0		0.112	
		1987.2745	80.4		0.104	
ADS 6862	I 489			72310		08315−1934
		1988.2520	346.9		0.230	
+28°1625	Cou 1115			—		08352+2811
		1986.8867	19.7		0.299	
+20°2148	Cou 47			73574		08397+2005
		1986.8839	143.4		0.540	
		1987.2664	143.9		0.520	
		1988.2576	143.3		0.533	
+19°2069	CHARA 130			73712		08402+1921
		1987.2664	163.9		0.088	
ADS 6930	Bu 585			73871		08412+2028
		1986.8840	86.4		0.488	
ADS 6993	SP AB			74874		08468+0625
		1986.8868	225.7		0.251	
		1987.2692	230.7		0.247	
ADS 7012	A 2552			75207		08486+0057
		1987.2720	110.4		0.163	
ADS 7039	A 2473			75470		08507+1800
		1986.8840	48.8		0.311	
ADS 7054	A 1584			75553		08531+5458
		1986.8868	346.0		0.121	
+20°2232	Cou 773			75974		08539+1958
		1986.8923	43.7		0.221	
		1988.2521	43.9		0.226	
ADS 7074	A 2554			76050		08539+0149
		1987.2692	357.2		0.242	
ADS 7071	STF 1291 AB			75959		08542+3034
		1986.8923	312.8		1.501	
ADS 7082	A 2131 AB			76095		08549+2613
		1986.8839	200.3		0.394	
ADS 7084	A 2132			76117		08557+4141
		1986.8922	201.6		0.186	
		1988.2521	201.7		0.189	
+36°1889	Cou 1897			76595		08585+3548
		1986.8922	170.6		0.176	
		1988.2521	175.3		0.168	
HR 3579	Kui 37 AB			76943		09008+4148
		1986.8839	301.8		0.463	
		1987.2690	293.7		0.455	
ADS 7158	A 1585			77327		09036+4709
		1986.8868	276.1		0.223	
		1988.2521	273.7		0.196	
HR 3635	CHARA 131			78661		09098+1134
		1986.8895	71.0		0.089	
HR 3650	Fin 347 Aa			79096		09123+1459
		1986.8895	317.4		0.164	
		1987.2637	303.7		0.140	
		1987.2692	303.5		0.139	
		1988.2521	289.9		0.059	
ADS 7284	STF 3121			79969		09180+2835
		1986.8840	221.0		0.423	
		1987.2692	224.2		0.402	
		1988.2577	232.2		0.328	
+19°2194	Cou 384			80082		09183+1847
		1986.8895	42.6		0.073	
		1987.2637	44.2		0.062	
ADS 7286	STF 1333			80024		09185+3522
		1988.2576	48.4		1.905	
ADS 7307	STF 1338 AB			80441		09210+3812
		1986.8923	264.6		1.033	
		1988.2548	267.2		1.024	
ADS 7334	A 1342 AB			81009		09229−0951
		1987.2692	30.5		0.162	
ADS 7352	STF 1348			81212		09245+0621
		1988.2577	316.2		1.996	
ADS 7341	A 2477			81163		09245+1808
		1986.8840	335.8		0.404	
		1987.2720	336.1		0.405	
		1988.2548	338.2		0.403	
		1988.2577	338.5		0.400	
ADS 7382	A 1588 AB			81728		09273−0913
		1987.2692	194.4		0.376	
		1988.2522	194.7		0.363	
HR 3750	B 2530			81809		09278−0604
		1987.2692	324.6		0.306	
		1988.2522	325.8		0.360	
ADS 7390	STF 1356			81858		09285+0904
		1986.8840	42.5		0.450	
		1987.2692	44.7		0.450	
		1988.2522	47.7		0.457	
+58°1192	Mlr 549			81772		09299+5808
		1987.2637	123.1		0.246	
HR 3794	Fin 349			82543		09326+0151
		1986.8895	172.9		0.162	
		1987.2692	174.7		0.158	
		1988.2522	179.5		0.157	
ADS 7456	STF 1372			83190		09371+1614
		1986.8895	85.1		0.091	
ADS 7457	A 1765			83158		09379+4554
		1987.2637	164.2		0.131	
ADS 7490	Hu 629			83887		09429+5035
		1987.2692	19.8		0.370	
		1988.2576	19.2		0.360	
HR 3880	McA 34			84722		09474+1134
		1987.2638	11.9		0.069	
		1988.2521	22.2		0.078	
+21°2108	Cou 284			84739		09477+2036
		1987.2638	59.0		0.145	
		1988.2521	56.9		0.141	
+00°2564	Rst 5339			85096		09496+0017
		1988.2577	194.8		0.724	
HR 3889	Kui 44			85040		09498+2111
		1987.2637	208.9		0.215	
		1988.2521	208.5		0.204	
ADS 7541	Ho 369 AB			85177		09512+3629
		1986.8840	101.4		0.403	
		1987.2665	101.5		0.399	
		1988.2576	101.1		0.395	
ADS 7545	STT 208			85235		09521+5404
		1987.2637	161.9		0.184	
		1988.2495	171.2		0.183	
		1988.2521	171.3		0.182	
ADS 7555	AC 5 AB			85558		09525−0806
		1986.8840	75.2		0.537	
		1987.2719	75.2		0.543	
		1988.2522	74.0		0.549	
		1988.2577	74.6		0.545	
+31°2066	Cou 1258			85708		09544+3041
		1987.2637	54.8		0.174	
+44°1931	Pop 151			85973		09566+4359
		1987.2665	78.9		0.497	
+39°2295	Cou 2086			86237		09581+3856
		1987.2637	65.7		0.185	
+34°2079	Cou 1569			87473		10059+3412
		1987.2637	85.2		0.113	
ADS 7651	Kui 48 AB			87822		10083+3137
		1987.2637	334.2		0.043	
		1988.2522	345.9		0.083	

TABLE II. (continued)

ADS 7662	A 2145			88021		10093+2020
		1987.2638	161.3		0.082	
ADS 7674	Hu 874			88355		10117+1321
		1987.2638	276.8		0.052	
		1988.2522	277.0		0.092	
ADS 7675	Ho 44			88478		10121−0613
		1986.8840	204.8		0.555	
		1987.2719	205.8		0.540	
		1988.2577	205.0		0.548	
ADS 7769	A 2570			90361		10260+0256
		1986.8840	306.1		0.333	
		1987.2638	307.4		0.336	
+20°2486	Cou 292			90460		10269+1931
		1987.2638	242.0		0.192	
ADS 7775	STT 217			90444		10270+1713
		1986.8840	144.0		0.540	
		1987.2665	144.3		0.543	
		1988.2577	144.9		0.551	
ADS 7780	Hu 879			90537		10279+3643
		1986.4038	233.3		0.384	
		1986.8840	233.2		0.370	
		1987.2665	233.8		0.356	
		1988.2496	235.1		0.322	
		1988.2549	235.3		0.321	
ADS 7788	A 2152			90698		10290+3452
		1988.2577	42.1		0.417	
ADS 7809	CHARA 132 Aa			91172		10311−2411
		1987.2719	176.1		0.110	
ADS 7844	A 2055 AB			91751		10366+4430
		1986.8840	163.9		0.348	
		1987.2667	163.2		0.343	
		1988.2577	164.4		0.341	
+35°2166	Cou 1417			91949		10376+3446
		1987.2693	205.4		0.299	
		1988.2577	206.3		0.300	
ADS 7896	A 2768			92749		10427+0335
		1987.2638	304.9		0.289	
		1988.2522	301.7		0.312	
ADS 7900	A 2769			92812		10432+0440
		1988.2577	217.3		0.501	
+26°2131	Cou 591			——		10472+2605
		1988.2577	7.2		0.423	
ADS 7926	STT 228			93392		10473+2235
		1986.8840	172.9		0.644	
		1987.2666	172.4		0.634	
		1988.2577	173.5		0.632	
ADS 7929	STT 229			93457		10481+4107
		1986.8840	277.3		0.769	
		1987.2667	277.5		0.763	
		1988.2549	277.1		0.760	
		1988.2577	276.0		0.754	
ADS 7952	A 2373			94120		10520+1606
		1987.2638	89.3		0.096	
+29°2110	Cou 960			95342		11008+2913
		1986.4093	101.6		0.198	
ADS 8047	Ho 378			96016		11050+3825
		1987.2693	55.6		0.970	
		1988.2578	55.3		0.967	
ADS 8051	A 2378			96130		11053+1635
		1988.2578	136.7		0.507	
HR 4314	Fin 47			96202		11053−2718
		1987.2720	227.5		0.170	
		1988.2550	222.1		0.178	
ADS 8086	Bu 220			97411		11124−1830
		1987.2720	326.4		0.297	
		1988.2549	324.1		0.291	
ADS 8092	A 1353			97455		11136+5525
		1986.4039	224.5		0.459	
		1988.2578	223.0		0.472	
ADS 8094	STF 1517			97561		11137+2008
		1986.8840	325.5		0.467	
		1987.2638	325.2		0.462	
		1988.2578	325.7		0.465	
ADS 8102	STT 232			97731		11150+3735
		1987.2666	59.0		0.622	
		1988.2578	58.4		0.620	
ADS 8104	Hu 639			97773		11154+4728
		1986.4066	86.7		0.100	
		1988.2523	89.6		0.115	
		1988.2549	89.5		0.112	
+43°2096	Cou 1904			97857		11158+4227
		1986.4038	199.6		0.338	
		1987.2639	200.4		0.348	
ADS 8117	A 2158			98087		11174+4146
		1987.2693	359.1		0.463	
		1988.2578	359.6		0.456	
HR 4380	CHARA 133			98353		11191+3811
		1987.2721	145.4		0.068	
ADS 8145	A 2776 AB			98914		11231+0408
		1987.2638	106.2		0.120	
-00°2442	Rst 4944			99651		11279−0142
		1987.2638	288.5		0.235	
		1988.2523	287.8		0.229	
ADS 8189	STT 234			100018		11308+4117
		1986.4039	137.2		0.352	
		1987.2640	138.8		0.365	
		1988.2523	141.3		0.383	
ADS 8198	Hu 1134			100235		11322+3615
		1986.4066	124.9		0.093	
		1987.2640	124.1		0.103	
ADS 8197	STT 235			100203		11324+6105
		1986.4039	264.7		0.536	
		1986.8842	267.7		0.543	
		1987.2667	269.3		0.556	
		1988.2549	272.9		0.564	
ADS 8210	Hu 727			233841		11332+4928
		1987.2693	22.4		1.243	
		1988.2578	21.7		1.264	
+48°1954	Cou 1573			——		11336+4729
		1988.2578	89.3		0.584	
ADS 8231	STF 1555 AB			100808		11363+2747
		1986.4039	144.7		0.621	
		1986.8842	144.0		0.622	
		1987.2667	144.7		0.627	
		1988.2523	145.0		0.633	
		1988.2578	146.0		0.630	
ADS 8249	STF 1559			101150		11388+6421
		1987.2693	323.1		2.002	
HR 4501	62 UMa			101606		11415+3145
		1987.2640	55.5		0.047	
		1988.2523	50.8		0.040	
-03°3167	Rst 5524			101969		11441−0448
		1988.2578	51.8		0.080	
HR 4528	CHARA 134			102510		11479+0815
		1987.2694	78.7		0.259	
+38°2283	Cou 1129			——		11499+3754
		1988.2605	145.4		0.560	
ADS 8347	A 1777 AB			103483		11551+4629
		1986.4066	179.6		0.103	
		1987.2695	186.3		0.102	
		1988.2523	196.1		0.095	
ADS 8387	A 1088			104288		12005+6912
		1986.4039	292.0		0.132	
ADS 8419	STF 3123 AB			105122		12061+6842
		1986.4039	293.1		0.164	
		1986.4066	295.2		0.170	
		1987.2640	288.7		0.173	
		1988.2550	284.6		0.180	
ADS 8433	A 1998			105369		12080+4242
		1988.2605	357.0		0.373	
HR 4632	CHARA 135			105778		12105+1649
		1987.2694	176.9		0.262	
ADS 8446	STF 1606			105824		12108+3954
		1986.4039	243.1		0.300	
		1986.8842	238.7		0.285	
		1987.2640	238.0		0.289	
		1988.2496	232.5		0.289	
		1988.2550	231.6		0.280	
HR 4642	CHARA 136			106022		12120+2832
		1987.2695	176.3		0.209	

TABLE II. (continued)

Star	Discoverer	Epoch	θ	ρ	HD	WDS
ADS 8485	Hu 736				106689	12160+4807
		1987.2693	219.9	0.261		
		1988.2605	217.8	0.263		
HR 4689	McA 37				107259	12199−0040
		1986.4067	57.1	0.093		
		1987.2640	92.2	0.088		
		1987.2667	91.3	0.088		
		1988.2496	129.4	0.103		
		1988.2550	132.5	0.099		
ADS 8535	STT 249 AB				107922	12238+5410
		1986.4039	266.0	0.411		
		1987.2694	265.7	0.405		
ADS 8540	STT 250				108005	12244+4306
		1987.2668	345.3	0.384		
ADS 8551	A 78				108320	12267−0535
		1987.2722	158.8	0.148		
HR 4789	WRH				109485	12348+2238
		1986.4041	7.5	0.303		
		1987.2642	6.6	0.291		
		1988.2496	5.9	0.273		
		1988.2550	6.1	0.272		
+27°2158	Cou 596				110297	12409+2708
		1986.4067	194.0	0.076		
ADS 8635	A 1851				110465	12422+2622
		1988.2579	266.2	0.502		
+43°2270	Cou 1579				—	12533+4246
		1988.2606	33.0	0.244		
ADS 8695	STF 1687 AB				112033	12533+2115
		1986.4041	170.2	1.017		
		1986.8842	170.5	1.018		
ADS 8708	STT 256				112398	12564−0057
		1988.2579	96.1	0.980		
+09°2696	Fin 380				112503	12572+0818
		1986.4067	155.6	0.148		
		1987.2642	154.8	0.156		
		1988.2496	156.8	0.161		
		1988.2524	156.8	0.171		
+25°2578	Cou 397				112572	12575+2457
		1987.2668	64.5	0.621		
		1988.2550	64.7	0.626		
		1988.2579	63.9	0.622		
ADS 8751	STF 1711				113322	13029+1328
		1988.2579	340.0	0.519		
ADS 8757	Bu 341				113415	13038−2035
		1987.2722	312.4	0.823		
		1988.2524	311.9	0.819		
ADS 8759	Bu 929				113459	13039−0340
		1987.2722	200.4	0.700		
Gliese 497	Wor 23				—	13048+5555
		1988.2578	153.4	1.592		
ADS 8785	A 1605				234012	13069+5200
		1988.2579	167.6	0.978		
ADS 8801	McA 38 Aa				114330	13100−0532
		1986.4067	331.3	0.490		
		1987.2642	329.9	0.475		
		1987.2723	330.8	0.477		
		1988.2498	330.9	0.467		
ADS 8804	STF 1728 AB				114378	13100+1731
		1986.4041	192.8	0.534		
		1987.2668	192.4	0.418		
		1988.2496	192.3	0.215		
HR 4978	Fin 305				114576	13117−2633
		1987.2722	98.3	0.169		
ADS 8825	A 1607				115002	13134+5252
		1988.2578	21.2	0.477		
ADS 8831	Fin 297 AB				114993	13145−2417
		1987.2722	145.9	0.224		
ADS 8843	STT 263				—	13167+5034
		1988.2579	135.6	1.854		
HR 5014	Fin 350				115488	13175−0041
		1986.4067	20.3	0.127		
		1987.2642	26.2	0.117		
		1988.2524	36.8	0.080		
ADS 8862	Hu 644				115953	13197+4747
		1988.2579	265.0	1.169		
ADS 8863	A 2166				115955	13202+1747
		1986.4067	327.7	0.058		
		1987.2642	340.2	0.083		
ADS 8864	STF 1734				115995	13207+0257
		1986.4095	178.6	1.144		
		1987.2723	178.1	1.129		
		1988.2579	178.4	1.139		
+43°2324	Cou 1581				116377	13225+4242
		1987.2642	159.6	0.266		
		1988.2606	159.1	0.263		
ADS 8887	Ho 260				116495	13236+2914
		1988.2579	75.9	1.266		
ADS 8901	A 1609 AB				116878	13258+4430
		1987.2642	303.8	0.255		
+33°2337	Cou 787				—	13266+3235
		1988.2606	150.3	0.334		
+31°2500	Wor 24				—	13320+3109
		1988.2606	272.6	0.224		
VW Com	Gliese 516 AB				—	13328+1649
		1988.2579	42.7	2.909		
+31°2508	Cou 600				—	13343+3044
		1988.2579	56.0	0.558		
ADS 8954	Du 932 AB				118054	13348−1313
		1986.4095	52.4	0.358		
		1987.2722	53.1	0.357		
		1988.2524	50.5	0.366		
ADS 8964	AG 190				—	13357+4939
		1988.2581	12.2	2.387		
ADS 8980	ES 608				—	13380+4808
		1988.2581	309.8	2.258		
ADS 8987	Bu 612 AB				118889	13396+1044
		1986.4069	216.9	0.308		
		1987.2642	220.0	0.305		
		1988.2498	224.3	0.297		
ADS 8988	Hu 897				—	13400+3759
		1988.2581	31.7	0.390		
ADS 9019	STF 1781				119931	13461+0507
		1986.4095	147.5	0.434		
		1987.2642	150.1	0.456		
		1988.2550	153.9	0.484		
		1988.2581	154.1	0.480		
HR 5178	Kui 65				120033	13472−0943
		1987.2642	239.5	0.311		
		1988.2550	237.9	0.300		
-13°3786	Rst 3852				121136	13539−1439
		1987.2722	133.8	0.158		
ADS 9066	STF 1792				—	13571+1227
		1988.2581	291.2	2.184		
ADS 9071	A 1614				121995	13576+5200
		1988.2581	129.9	1.289		
Gliese 9465	Ald 112				—	14019+1530
		1988.2581	179.4	1.667		
ADS 9089	A 1097 AB				122740	14020+5713
		1988.2581	229.8	0.414		
+14°2691	Hei 65				122654	14029+1417
		1988.2581	119.9	0.472		
ADS 9094	Bu 1270				122769	14037+0829
		1986.4069	81.4	0.140		
		1987.2670	98.6	0.126		
		1988.2606	111.9	0.117		
ADS 9121	STT 276 AB				123670	14082+3645
		1988.2581	205.7	0.492		
ADS 9159	STT 278				124399	14120+4411
		1987.2670	309.6	0.322		
ADS 9158	STT 277 AB				124346	14124+2843
		1986.4042	42.1	0.306		
		1987.2670	42.6	0.297		
		1988.2606	41.4	0.294		
ADS 9169	A 1100				124492	14138+0859
		1987.2670	173.8	0.298		
		1988.2606	172.9	0.304		
+31°2596	Cou 606				—	14138+3100
		1986.4069	187.4	0.119		
ADS 9174	STF 1816				124587	14139+2906
		1987.2670	89.5	0.721		
		1988.2581	89.8	0.700		

TABLE II. (continued)

ADS 9182	STF 1819				124757	14153+0308
		1988.2579	224.3	0.881		
ADS 9220	A 1102				125725	14180+6914
		1986.4041	102.0	0.392		
+64°0993	Mlr 168				—	14187+6409
		1988.2581	115.1	0.228		
ADS 9215	STF 1832 AB				125377	14189+0354
		1988.2581	151.7	0.431		
HR 5372	CHARA 137				125632	14189+5452
		1987.2698	13.5	0.103		
+31°2612	Cou 482				—	14213+3050
		1988.2581	120.4	0.608		
ADS 9238	A 148				126126	14220+5107
		1988.2581	5.5	0.630		
ADS 9247	Bu 1111 BC				126128	14234+0827
		1987.2668	58.7	0.257		
		1988.2499	68.2	0.255		
		1988.2526	62.1	0.244		
+16°2642	McA 39				126269	14241+1617
		1987.2670	158.4	0.048		
		1988.2526	153.8	0.065		
ADS 9264	A 2069				126695	14268+1625
		1986.4070	354.0	0.211		
+21°2659	Cou 97				—	14304+2255
		1988.2607	244.5	0.350		
ADS 9301	A 570				127726	14323+2641
		1986.4070	283.2	0.155		
		1987.2670	268.0	0.161		
		1988.2498	252.5	0.169		
		1988.2524	252.5	0.169		
ADS 9313	AGC 6				128042	14339+2949
		1988.2582	134.9	0.772		
ADS 9318	Bu 941 AB				128233	14358+0015
		1988.2607	150.6	0.250		
ADS 9324	A 347				128718	14369+4813
		1987.2671	266.8	0.565		
		1988.2581	266.4	0.567		
ADS 9323	CHARA 42 Aa				128563	14373+0217
		1986.4042	165.6	0.201		
		1987.2643	169.5	0.197		
		1988.2526	173.1	0.172		
ADS 9329	STF 1863				128941	14381+5135
		1986.4043	67.4	0.651		
		1987.2671	67.0	0.651		
		1988.2581	66.6	0.648		
ADS 9334	A 1107				129006	14401+0504
		1988.2582	86.0	0.456		
HR 5472	McA 40				129132	14403+2158
		1986.4070	91.5	0.048		
		1987.2643	82.2	0.066		
		1988.2526	68.5	0.064		
ADS 9343	STF 1865 AB				129246	14411+1344
		1986.4095	303.9	0.962		
		1987.2671	303.4	0.958		
		1987.2751	303.5	0.955		
		1988.2499	303.5	0.930		
ADS 9352	Hu 575 AB				—	14426+1930
		1986.4043	316.7	0.392		
		1988.2582	294.0	0.325		
ADS 9378	STT 285				130188	14455+4222
		1986.4043	318.4	0.325		
		1987.2642	316.1	0.336		
+24°2770	Cou 100				—	14459+2343
		1987.2643	295.7	0.148		
		1988.2607	289.0	0.137		
HR 5504	Fin 309				129980	14462−2110
		1986.4070	298.5	0.258		
		1987.2725	306.6	0.280		
ADS 9392	STF 1883				130604	14489+0557
		1986.4042	289.4	0.535		
		1987.2671	288.7	0.558		
		1988.2551	288.2	0.588		
ADS 9400	A 1110 AB				130726	14497+0800
		1986.4042	247.2	0.639		
		1987.2671	247.1	0.635		
ADS 9425	STT 288				131473	14534+1543
		1986.4043	170.9	1.357		
Gliese 568	Ross 52				—	14539+2333
		1988.2582	75.3	0.611		
ADS 9443	A 2172				131954	14565+0255
		1988.2607	175.5	0.085		
ADS 9453	Bu 239				132219	14587−2739
		1987.2725	351.9	0.565		
ADS 9459	A 2173				—	14590+0059
		1988.2607	131.2	0.271		
+47°2190	Cou 1760				—	14593+4649
		1986.4070	206.8	0.212		
		1988.2609	209.2	0.203		
+18°2966	Cou 188				—	15005+1753
		1988.2607	227.1	0.285		
ADS 9480	Bu 348 AB				132933	15018+0008
		1986.4042	109.6	0.508		
HR 5612	CHARA 43				133484	15031+4439
		1986.4070	91.0	0.168		
		1988.2527	105.0	0.115		
ADS 9494	STF 1909				133640	15039+4739
		1986.4095	44.9	1.397		
		1988.2500	46.3	1.514		
+40°2856	Cou 1271				134303	15078+3956
		1988.2582	166.2	0.388		
		1988.2609	165.7	0.382		
+40°2859	Cou 1272				—	15088+4013
		1988.2609	51.4	0.284		
ADS 9515	Rst 4534 AB				134213	15089−0610
		1987.2725	12.4	0.367		
		1988.2582	12.0	0.369		
ADS 9530	A 1116				134827	15116+1008
		1986.4098	47.1	0.759		
		1987.2671	47.1	0.749		
		1988.2582	46.9	0.767		
HR 5654	Cou 189				134943	15121+1858
		1986.4098	144.7	0.460		
		1987.2671	143.6	0.459		
		1988.2499	145.5	0.473		
ADS 9532	B 2351 Aa				134759	15123−1947
		1987.2725	330.0	0.138		
ADS 9547	Ho 60				135365	15136+3453
		1988.2607	170.8	0.087		
-12°4227	CHARA 44				135681	15168−1302
		1986.4098	173.9	0.156		
ADS 9578	STF 1932 AB				136176	15183+2649
		1988.2499	254.1	1.501		
ADS 9589	A 1630				—	15192+4329
		1988.2582	248.5	0.775		
+24°2847	Cou 103				—	15200+2338
		1988.2582	281.7	0.536		
HR 5715	CHARA 46				136729	15201+5158
		1987.2644	92.2	0.166		
ADS 9600	Hu 146				136596	15210+2104
		1988.2582	128.6	0.633		
ADS 9617	STF 1937 AB				137107	15232+3018
		1986.4044	14.4	0.914		
		1988.2499	20.2	0.992		
		1988.2526	20.5	0.990		
+40°2878	Cou 1441				—	15233+4022
		1986.4043	17.1	0.259		
		1988.2609	16.6	0.256		
+61°1505	Mlr 346				—	15259+6032
		1988.2582	31.6	0.273		
HR 5747	β CrB				137909	15278+2906
		1986.4044	145.6	0.306		
		1987.2644	140.7	0.282		
		1988.2499	134.1	0.220		
		1988.2526	134.1	0.221		
ADS 9682	Hu 1163				138439	15307+3810
		1987.2644	50.7	0.109		
ADS 9688	A 1634 AB				138629	15318+4053
		1988.2609	33.0	0.050		
HR 5778	Cou 610				138749	15329+3121
		1986.4044	202.3	0.719		
		1988.2499	201.2	0.737		

TABLE II. (continued)

ADS 9694	STF 1956		138884		15333+4149
	1988.2582	34.0		0.347	
+27°2513	Cou 798		——		15347+2655
	1986.4097	65.9		0.133	
	1988.2607	69.4		0.123	
ADS 9716	STT 298 AB		139341		15361+3948
	1986.4043	257.3		0.329	
	1988.2500	287.8		0.283	
ADS 9730	Hu 1168		139905		15370+6426
	1988.2609	180.5		0.121	
ADS 9731	STF 1964 CD		139691		15382+3614
	1986.4043	18.6		1.584	
+26°2712	Cou 612		139749		15390+2545
	1986.4044	255.0		0.188	
	1987.2643	250.6		0.193	
ADS 9735	Bu 122		139628		15399−1947
	1988.2582	222.8		1.840	
ADS 9742	A 2076		139939		15405+1841
	1986.4098	180.9		0.674	
	1988.2582	181.4		0.680	
ADS 9756	STF 1969		140590		15413+5959
	1988.2582	23.4		0.642	
ADS 9744	Hu 580 AB		140159		15416+1941
	1986.4097	48.1		0.047	
	1987.2643	58.8		0.099	
	1988.2527	63.9		0.149	
+42°2629	Cou 1445		140432		15420+4204
	1986.4071	227.8		0.107	
	1987.2644	222.2		0.104	
	1988.2527	222.8		0.087	
ADS 9757	STF 1967		140436		15428+2618
	1986.4097	120.0		0.507	
	1988.2500	119.1		0.547	
ADS 9758	Bu 619		140438		15431+1340
	1986.4098	4.7		0.703	
+22°2878	Cou 106		140629		15440+2220
	1986.4097	272.7		0.394	
	1988.2556	272.1		0.392	
+30°2703	Cou 614		140889		15451+2936
	1988.2556	38.8		0.336	
ADS 9783	A 2077		——		15469+1904
	1988.2583	229.4		0.557	
ADS 9794	A 1127		141730		15474+5929
	1986.4043	290.4		0.326	
	1988.2582	289.0		0.314	
	Cou 1918		234262		15486+4949
	583	7.5		0.335	
	.609	8.7		0.347	
ADS [illegible]	Hu 912		142080		15492+6032
	1986.4071	311.1		0.136	
	1987.2644	316.4		0.075	
HR 5895	CHARA 51		141851		15513−0305
	1987.2726	194.8		0.112	
	1988.2527	185.2		0.101	
ADS 9812	Hu 153		141898		15519−1232
	1987.2726	70.2		0.428	
	1988.2556	70.4		0.416	
ADS 9834	Hu 1274		142378		15550−1923
	1987.2726	121.0		0.563	
ADS 9836	I 977		142456		15557−2645
	1987.2726	175.3		0.237	
	1988.2556	178.3		0.229	
HR 5953	δ Sco		143275		16003−2237
	1987.2726	183.5		0.157	
ADS 9909	STF 1998 AB		144069		16044−1122
	1987.2726	34.9		0.672	
	1988.2528	37.0		0.322	
ADS 9918	Fin 384 Aa		144362		16057−0617
	1988.2527	177.8		0.050	
ADS 9931	A 1798		144935		16070+1425
	1986.4098	26.1		0.191	
ADS 9935	Bu 355 AB		145246		16081+4524
	1986.4044	281.2		0.269	
	1986.4099	281.6		0.262	
	1987.2644	281.0		0.267	
	1988.2527	282.6		0.259	
ADS 9932	Bu 949		144892		16085−1006
	1987.2726	194.6		0.457	
	1988.2556	194.5		0.465	
ADS 9952	A 1799		145648		16115+1507
	1988.2556	123.1		0.677	
HR 6032	Fin 354		145589		16115+0943
	1986.4098	84.0		0.127	
	1987.2726	84.9		0.125	
	1988.2501	83.3		0.122	
	1988.2527	83.2		0.118	
ADS 9971	Rst 3936 AB		145996		16143−1024
	1987.2726	269.6		0.290	
	1988.2556	267.2		0.285	
ADS 10006	STT 309		147275		16192+4140
	1986.4044	286.6		0.317	
	1987.2644	288.3		0.314	
	1988.2500	288.5		0.306	
HR 6084	σ Sco Aa		147165		16212−2536
	1987.2726	84.5		0.407	
HR 6103	CHARA 53 Aa		147677		16221+3053
	1986.4098	93.0		0.163	
-16°4280	CHARA 54		147473		16229−1701
	1987.2726	81.2		0.127	
ADS 10052	STF 2054 AB		148374		16238+6142
	1986.4044	352.9		1.053	
	1988.2529	352.5		1.044	
ADS 10052	CHARA 138 Aa		148374		16238+6142
	1986.4044	174.0		0.211	
HR 6123	CHARA 55		148283		16254+3724
	1986.4099	175.7		0.168	
	1987.2645	172.4		0.128	
ADS 10068	Bu 814		148552		16272+3952
	1986.4044	354.6		0.327	
-15°4324	Rst 3950		148394		16286−1613
	1987.2726	59.4		0.285	
ADS 10075	STF 2052 AB		148653		16289+1825
	1986.4044	130.8		1.661	
	1987.2728	130.0		1.689	
ADS 10078	A 2084		——		16296+1635
	1988.2556	144.3		0.494	
ADS 10085	Hu 1173		148909		16300+3354
	1986.4098	43.6		0.190	
	1987.2672	42.5		0.193	
ADS 10087	STF 2055 AB		148857		16310+0159
	1986.4098	17.7		1.306	
	1987.2727	18.2		1.314	
	1988.2501	19.2		1.329	
ADS 10092	STF 3105		148931		16318−0702
	1987.2727	198.8		0.375	
	1988.2556	197.9		0.385	
HR 6168	σ Her		149630		16341+4227
	1977.1781	24.9		0.079	
	1977.3284	22.5		0.080	
	1986.4099	194.1		0.115	
	1987.2672	188.8		0.102	
	1988.2529	182.9		0.080	
ADS 10140	Bu 953 AB		150631		16367+6948
	1988.2556	101.6		0.310	
ADS 10149	CHARA 56 Ba		150379		16406+0412
	1988.2501	88.9		0.212	
ADS 10169	STF 2091		150903		16422+4112
	1988.2556	318.1		0.574	
ADS 10189	Hu 664		151267		16437+5132
	1986.4044	303.0		0.480	
	1988.2556	303.0		0.475	
ADS 10184	STF 2094 AB		151070		16442+2331
	1986.4099	74.4		1.233	
	1988.2556	74.2		1.228	
+29°2876	Cou 490		151236		16450+2928
	1986.4099	18.1		0.211	
ADS 10229	STF 2106		152113		16511+0925
	1986.4045	179.9		0.593	
	1987.2672	178.7		0.603	
	1988.2501	179.1		0.611	

TABLE II. (continued)

ADS 10230	STT 315			152127		16515+0113
		1987.2672	337.9		0.277	
		1988.2501	335.9		0.304	
		1988.2528	335.5		0.301	
+26°2915	Cou 492			——		16539+2547
		1988.2556	92.3		0.552	
ADS 10253	A 350			152747		16540+2906
		1988.2556	146.7		0.564	
ADS 10252	B 323			152535		16550−2431
		1988.2556	89.2		0.464	
ADS 10257	Bu 241			152655		16555−2134
		1987.2727	8.7		0.363	
		1988.2556	11.1		0.372	
ADS 10279	STF 2118			153697		16563+6502
		1986.4044	69.8		1.133	
		1988.2529	69.5		1.127	
ADS 10268	Hu 160			152995		16566+1014
		1988.2556	205.4		0.457	
ADS 10276	A 1143 AB			153495		16566+5711
		1988.2556	303.0		0.475	
ADS 10265	Bu 1117			152849		16568−2309
		1987.2727	290.0		0.982	
ADS 10287	Hu 162			153305		16593−1655
		1988.2556	213.6		0.667	
ADS 10294	STT 321			153490		16594+1419
		1988.2557	12.4		0.582	
ADS 10295	Bu 1298 AB			153475		16595+0942
		1988.2557	124.2		0.427	
ADS 10312	STF 2114			153914		17019+0827
		1986.4045	188.1		1.294	
		1987.2727	188.1		1.294	
ADS 10340	A 1146			155090		17052+6947
		1988.2556	123.3		0.379	
ADS 10345	STF 2130 AB			154905		17054+5427
		1986.4044	37.4		2.122	
+38°2885	Cou 1291			155039		17075+3810
		1987.2673	234.9		0.116	
ADS 10360	Hu 1176 AB			155103		17081+3555
		1986.4099	110.3		0.137	
		1987.2673	99.0		0.127	
		1988.2531	82.2		0.104	
HR 6396	ζ Dra			155763		17088+6543
		1987.2673	22.9		0.095	
-19°4547	McA 46			155095		17103−1926
		1987.2699	111.8		0.132	
+49°2600	Cou 1775			——		17115+4914
		1988.2557	81.5		0.459	
+45°2505	Kui 79 AB			155876		17121+4544
		1986.4045	226.3		1.109	
		1988.2557	209.5		0.920	
ADS 10418	CHARA 130 Aa			156014		17146+1423
		1986.4100	85.8		0.192	
ADS 10464	Hu 669			234420		17182+4952
		1988.2557	81.2		0.834	
ADS 10469	Swi			157103		17183+5338
		1988.2557	166.6		0.513	
ADS 10459	Bu 628			——		17184+3239
		1986.4045	283.1		0.476	
		1988.2557	281.1		0.470	
ADS 10495	A 232			157256		17212+2542
		1988.2557	117.3		0.461	
HR 6469	McA 47			157482		17217+3958
		1987.2673	140.9		0.080	
		1988.2529	157.5		0.107	
+23°3092	Cou 415			157392		17221+2310
		1986.4100	25.6		0.124	
ADS 10504	Ho 414 AB			157429		17222+2605
		1988.2557	100.8		0.798	
+21°3107	Cou 201 AB			157430		17224+2056
		1988.2557	255.0		0.545	
ADS 10523	STF 2163			——		17233+4209
		1988.2557	80.1		1.470	
ADS 10531	Hu 1179			157853		17241+3834
		1986.4102	285.9		0.092	
		1987.2673	285.9		0.103	
		1988.2529	284.5		0.117	
		1988.2610	284.1		0.118	
+26°3022	Cou 498			——		17276+2624
		1988.2583	47.5		0.416	
ADS 10589	Ho 417			158755		17293+3758
		1988.2583	136.2		0.363	
ADS 10585	A 351			——		17294+2924
		1988.2583	246.9		0.686	
ADS 10598	STF 2173			158614		17303−0103
		1986.4100	336.7		0.993	
		1988.2583	335.8		1.066	
+19°3336	Cou 499			158956		17313+1901
		1986.4100	69.5		0.159	
HR 6560	Mlr 571			159870		17335+5734
		1986.4102	345.1		0.144	
+45°2566	Cou 1595			160214		17365+4543
		1988.2583	254.6		0.441	
ADS 10659	A 1156			159857		17366+0722
		1986.4100	355.9		0.091	
+27°2853	Kui 83 AB			——		17370+2753
		1988.2583	244.8		0.245	
		1988.2610	244.9		0.248	
ADS 10669	Bu 1121			160058		17374+1233
		1988.2583	207.4		0.502	
HR 6571	CHARA 63			160181		17375+2419
		1986.4100	65.0		0.101	
		1987.2700	58.9		0.097	
		1988.2611	51.0		0.087	
ADS 10696	Bu 631			160438		17399−0039
		1986.4100	129.4		0.114	
		1988.2610	118.9		0.133	
+21°3188	Cou 114			160935		17418+2130
		1986.4045	32.7		0.289	
		1987.2700	32.7		0.284	
ADS 10743	Hu 1285			161258		17436+2237
		1986.4045	222.1		0.562	
		1988.2583	221.4		0.563	
ADS 10794	Hu 924			——		17449+6628
		1988.2583	206.1		0.301	
ADS 10773	Ho 70			161675		17456+3032
		1988.2583	93.3		0.431	
ADS 10800	A 697			162051		17471+4215
		1988.2583	116.7		0.535	
HR 6641	CHARA 64			162132		17471+4737
		1987.2700	116.0		0.170	
		1988.2611	117.5		0.179	
ADS 10796	Hu 1288			161819		17472+1502
		1988.2583	152.4		0.425	
ADS 10795	STF 2215			161833		17472+1742
		1986.4045	265.2		0.561	
		1987.2699	265.3		0.559	
		1988.2583	265.0		0.549	
ADS 10814	Hu 1182			——		17486+3536
		1988.2583	324.6		0.603	
ADS 10815	J 754 AB			——		17490+2450
		1988.2583	49.3		1.801	
ADS 10822	A 2187			162262		17501+0214
		1988.2557	322.1		0.482	
ADS 10828	STT 337			162405		17505+0715
		1986.4045	177.1		0.413	
		1988.2583	176.5		0.420	
ADS 10848	Hu 1183			——		17512+3821
		1988.2583	188.4		0.449	
ADS 10846	A 1164			162670		17519+0724
		1986.4045	42.8		0.373	
		1988.2557	42.5		0.376	
ADS 10850	STT 338 AB			162734		17520+1520
		1986.4045	351.3		0.833	
ADS 10866	AC 8			163032		17528+2941
		1986.4102	273.9		0.202	
+42°2942	Cou 1599			——		17530+4212
		1988.2583	127.4		0.603	
ADS 11006	STT 349			167101		17530+8354
		1986.4047	46.1		0.401	
		1987.2700	44.5		0.395	
		1988.2584	44.8		0.398	
ADS 10871	A 235			163077		17533+2500
		1986.4045	81.4		0.403	
		1988.2583	83.9		0.401	

TABLE II. (continued)

HR 6676	Fin 381				163151	17543+1108
		1986.4100	257.9	0.099		
		1987.2700	231.8	0.082		
		1988.2611	190.5	0.063		
+41°2928	Cou 1601 Aa				—	17556+4108
		1986.4045	66.3	0.533		
		1988.2584	64.6	0.535		
+25°3381	Cou 503				163529	17556+2508
		1986.4045	90.4	0.368		
		1988.2584	92.2	0.362		
ADS 10905	McA 49 Aa				163640	17564+1820
		1988.2610	67.3	0.086		
ADS 10905	STF 2245 Aa,B				163640	17564+1820
		1987.2755	291.9	2.627		
ADS 10912	STF 2244				163624	17571+0004
		1986.4100	92.7	0.343		
HR 6697	McA 50				163840	17572+2400
		1988.2612	336.6	0.085		
ADS 11005	STF 2262 AB				164764	18030−0811
		1988.2584	279.4	1.861		
ADS 11060	STT 341 AB				165590	18059+2126
		1986.4047	91.3	0.494		
		1987.2700	91.3	0.497		
ADS 11071	Hu 1186				—	18063+3824
		1986.4047	104.0	0.436		
		1988.2584	104.4	0.423		
ADS 11080	STT 524				165886	18075+1939
		1986.4047	223.5	0.314		
		1987.2700	221.8	0.321		
		1988.2584	222.0	0.322		
ADS 11089	CHARA 67 Aa				166045	18078+2606
		1987.7617	112.4	0.127		
ADS 11111	STF 2281 AB				166233	18095+0401
		1986.4047	318.4	0.382		
		1988.2584	316.2	0.392		
ADS 11128	Hu 674				166820	18097+5024
		1986.4047	226.8	0.722		
		1988.2584	225.9	0.727		
ADS 11123	STF 2289				166479	18102+1628
		1986.4047	221.9	1.219		
		1988.2584	221.0	1.207		
ADS 11144	A 238				166822	18113+2519
		1988.2584	77.1	0.615		
ADS 11149	B 2545 AB				166988	18117+3327
		1986.4047	66.0	0.102		
		1987.7617	69.6	0.096		
ADS 11170	Bu 1091				—	18126+3836
		1988.2584	326.8	0.602		
-20°5068	McA 51				167570	18167−2032
		1987.2700	134.1	0.258		
HR 6851	CHARA 68				168199	18180+1347
		1987.2728	39.7	0.058		
		1987.7617	41.9	0.058		
		1988.2612	42.8	0.057		
ADS 11311	STT 353				170000	18207+7120
		1986.4047	277.4	0.357		
HR 6927	χ Dra				170153	18208+7245
		1987.7617	226.4	0.129		
ADS 11324	AC 11				169493	18249−0135
		1986.4047	356.3	0.868		
ADS 11344	Hu 66 AB				170109	18253+4845
		1986.4047	249.6	0.318		
		1987.7562	248.2	0.311		
ADS 11344	STT 351 AC				170109	18253+4845
		1986.4047	18.4	0.705		
		1987.7562	18.2	0.708		
ADS 11339	Bu 1203				169725	18261+0046
		1986.4047	145.5	0.415		
HR 6928	CHARA 71				170200	18280+0612
		1987.2728	114.9	0.080		
		1987.7535	113.2	0.075		
		1987.7589	112.9	0.082		
ADS 11399	CHARA 72 Aa				170580	18301+0404
		1987.2728	178.1	0.152		
ADS 11458	Ho 86				—	18335+3510
		1987.7562	188.9	0.327		
ADS 11454	STF 2339 AB,C				171365	18338+1744
		1987.7562	276.1	1.667		
ADS 11454	Hu 322 AB				171365	18338+1744
		1987.7562	89.0	0.226		
ADS 11468	A 1377 AB				171779	18340+5221
		1987.7563	102.2	0.262		
HR 6977	CHARA 74				171623	18352+1812
		1987.2728	26.9	0.149		
		1987.7537	24.7	0.154		
HR 6984	CHARA 75				171780	18352+3427
		1987.7537	79.3	0.239		
ADS 11479	STT 359				171745	18355+2336
		1986.4048	9.4	0.659		
		1987.7562	8.8	0.666		
+21°3492	Cou 206				342628	18363+2143
		1987.7590	127.1	0.105		
ADS 11496	CHARA 76 Aa				171834	18367+0640
		1987.2728	91.4	0.159		
ADS 11502	Hu 247				171929	18370+1016
		1987.7562	13.2	0.473		
ADS 11520	A 88 AB				172088	18384−0312
		1987.2728	322.1	0.135		
		1987.7589	313.4	0.128		
ADS 11530	Ho 87 AB				172246	18386+1632
		1987.7535	45.8	0.279		
ADS 11558	STF 2368 AB				172712	18389+5221
		1986.4048	322.2	1.921		
HR 7017	Cou 1607				172671	18395+4056
		1987.7537	115.2	0.174		
ADS 11566	Ho 437 AB				172729	18406+3138
		1986.4048	131.8	0.418		
		1987.7562	131.8	0.411		
ADS 11574	A 2988				172743	18410+2450
		1987.7537	166.1	0.121		
ADS 11579	STF 2367 AB				172865	18413+3018
		1987.7537	89.0	0.160		
		1987.7590	89.4	0.164		
ADS 11593	B 2546 Aa				173087	18421+3445
		1987.7537	306.5	0.144		
+18°3786	Cou 816				229303	18433+1847
		1987.7562	300.7	0.251		
ADS 11640	Fin 332 Aab				173495	18455+0530
		1987.7618	129.2	0.117		
ADS 11640	Fin 332 Bab				173495	18455+0530
		1987.7618	137.8	0.146		
ADS 11683	Hu 584				229505	18475+1537
		1987.7562	13.6	0.401		
ADS 11698	Bu 971 AB				174343	18475+4926
		1986.4048	37.2	0.325		
ADS 11687	Hu 252				173923	18477+0916
		1987.7562	135.4	0.461		
HR 7090	Hei 72				174366	18477+4905
		1986.4048	217.5	0.515		
		1987.7562	218.3	0.523		
-18°5070	Rst 3198				173805	18480−1814
		1988.2584	155.4	0.404		
ADS 11709	Hu 326				343145	18486+2330
		1987.7590	176.7	0.096		
HR 7109	CHARA 80				174853	1852[illegible]+1358
		1987.7592	87.0	0.063		
ADS 11897	STF 2438				176560	18575+5814
		1986.4048	3.0	0.841		
		1987.7563	2.4	0.844		
ADS 11884	CHARA 82 Aa				176155	18582+1722
		1987.7592	182.2	0.233		
HR 7166	Kui 89				176162	18594−1250
		1987.7592	294.9	0.129		
+39°3606	Cou 1933				176669	19006+3951
		1987.7563	200.1	0.498		
ADS 12033	Hu 940				—	19055+3352
		1987.7563	202.7	0.562		
+35°3478	Cou 1614				—	19060+3549
		1987.7563	126.3	0.505		
HR 7262	ι Lyr				178475	19073+3606
		1987.7590	39.4	0.079		
HR 7263	CHARA 83				178476	19081+2142
		1987.7590	3.2	0.213		

TABLE II. (continued)

ADS 12079	Ho 98 AB				178617	19081+2705
		1987.7563	86.2	0.263		
+12°3818	McA 54				178452	19083+1215
		1987.7565	179.8	0.165		
		1987.7592	183.6	0.170		
+10°3801	CHARA 140				178717	19094+1014
		1985.4927	29.2	0.250		
HR 7362	Fin 327				182369	19253−2431
		1988.2612	90.5	0.087		
ADS 12540	McA 55 Aa				183912	19307+2758
		1986.8883	163.2	0.410		
		1987.7618	161.2	0.407		
+58°1929	McA 56				184467	19311+5835
		1986.8883	128.5	0.065		
		1987.7618	172.7	0.067		
ADS 12567	A 713				184242	19313+4729
		1986.4048	272.6	0.354		
HR 7436	CHARA 87				184603	19336+3846
		1986.8883	177.8	0.141		
		1987.7618	183.2	0.139		
HR 7441	9 Cyg				184759	19348+2928
		1987.7620	12.1	0.043		
ADS 12973	AGC 11 AB				187362	19489+1908
		1987.7620	171.7	0.221		
+29°3867	Cou 1473				333412	20027+2939
		1986.8855	355.4	0.501		
ADS 13312	McA 59 Aa				190429	20035+3602
		1986.8855	55.4	0.206		
HR 7684	CHARA 91				190781	20045+4814
		1986.8855	205.7	0.352		
HR 7677	CHARA 92				190590	20050+2313
		1986.8884	70.6	0.039		
ADS 13384	Bu 428				190887	20067+1256
		1985.4928	353.7	0.789		
ADS 13564	A 1204				192559	20143+3129
		1986.8855	139.7	0.359		
ADS 13572	STT 403 AB				192659	20143+4206
		1986.8855	170.4	0.931		
ADS 13611	A 2095 AB				192911	20156+4339
		1987.7537	158.1	0.201		
HR 7755	CHARA 93				192983	20157+5014
		1987.7537	186.5	0.165		
HR 7744	McA 60 Aa,B				192806	20158+2749
		1986.8884	142.4	0.274		
		1987.7538	141.9	0.279		
ADS 13660	BAR 11 AB				193238	20180+3311
		1986.8855	197.3	0.383		
ADS 13672	CHARA 96 Aa				193322	20181+4044
		1986.8884	198.7	0.049		
ADS 13686	A 1425 AB				193443	20189+3817
		1987.7537	266.1	0.139		
ADS 13728	A 1427 AB				193702	20202+3924
		1986.8855	109.3	0.332		
+19°4380	Cou 327 AB				193797	20216+1930
		1987.7538	67.1	0.065		
ADS 13777	A 288				194113	20232+2052
		1987.7538	223.6	0.117		
ADS 13820	A 1428				194523	20239+5232
		1986.8855	209.6	0.323		
ADS 13834	A 290				194540	20249+3404
		1987.7538	131.8	0.448		
+35°4115	Cou 2130 Aa				194760	20262+3547
		1987.7537	56.4	0.153		
+33°3914	Cou 1956				195102	20281+3353
		1987.7538	236.6	0.334		
ADS 13944	A 1675				195481	20311+1548
		1987.7539	189.6	0.070		
ADS 13946	CHARA 99 Aa				195482	20312+1116
		1987.7620	126.6	0.350		
ADS 13939	Bu 671				196069	20317+6227
		1986.8855	318.6	0.485		
+49°3310	McA 61				196089	20331+4950
		1987.7620	149.6	0.033		
HR 7866	WRH AB				196093	20339+3515
		1986.8966	96.2	0.282		
ADS 14073	Bu 151 AB				196524	20375+1436
		1987.7620	136.0	0.200		
ADS 14126	STT 410 AB				197018	20396+4036
		1986.8856	6.1	0.841		
		1986.8966	6.3	0.841		
ADS 14121	WCK Aa				196867	20397+1556
		1986.8965	269.7	0.160		
		1987.7620	257.1	0.178		
ADS 14148	A 2795				197075	20406+2156
		1986.8965	252.1	0.245		
HR 7922	McA 62				197226	20410+3905
		1987.7620	100.8	0.055		
+34°4117	Cou 1963 AB				—	20411+3516
		1986.8856	3.7	0.257		
ADS 14238	Bu 64 AB				197683	20451+1244
		1987.7620	165.5	0.653		
ADS 14296	STT 413 Aa,B				198183	20474+3629
		1986.8856	14.7	0.852		
ADS 14306	Bu 268				198253	20476+4204
		1986.8856	202.3	0.427		
ADS 14379	Ho 144				198810	20523+2008
		1986.8965	345.3	0.335		
ADS 14404	Ho 146				199071	20536+3514
		1987.7566	50.5	0.361		
ADS 14412	A 751				199306	20538+5919
		1986.8966	139.3	0.147		
		1987.7565	135.7	0.154		
ADS 14493	A 756 AB				199937	20577+5850
		1986.8856	213.6	0.566		
		1987.7565	213.9	0.565		
ADS 14504	STF 2741 AB				199955	20586+5028
		1987.7565	26.1	1.944		
ADS 14499	STF 2737 AB				199766	20591+0418
		1986.8910	285.3	0.977		
		1987.7566	285.7	0.971		
ADS 14505	STT 424 AB				199839	20593+1534
		1986.8910	306.3	0.527		
		1987.7566	308.0	0.527		
ADS 14526	McA 65 Aa				200120	20598+4732
		1986.8910	48.3	0.207		
		1987.7565	47.4	0.207		
HR 8038	Kui 102				199942	21002+0731
		1986.8910	46.9	0.324		
		1987.7566	44.1	0.329		
ADS 14543	A 1438				200222	21010+4000
		1987.7566	248.4	0.289		
ADS 14575	STF 2751				200614	21022+5640
		1987.7565	354.0	1.633		
ADS 14617	Hu 590				200927	21048+4902
		1987.7565	86.2	0.246		
+39°4427	Cou 2135				200890	21050+4021
		1987.7566	355.9	0.216		
ADS 14634	Hu 765 BC				201267	21055+6210
		1987.7565	30.5	0.754		
ADS 14644	Hu 691				201155	21067+3455
		1987.7568	312.8	0.346		
ADS 14666	STT 527				201221	21080+0509
		1986.8910	134.4	0.232		
		1987.7566	133.4	0.237		
+28°4003	Cou 1332				—	21091+2922
		1987.7566	18.7	0.211		
+39°4463	Cou 1968				—	21098+4013
		1987.7566	97.9	0.179		
ADS 14749	STF 2780 Aa,B				202214	21118+6000
		1986.8856	215.3	1.052		
		1987.7620	215.5	1.054		
ADS 14749	McA 67 Aa				202214	21118+6000
		1986.8856	29.7	0.050		
		1987.7620	25.4	0.057		
ADS 14761	Hu 767				202123	21135+1559
		1986.8910	75.1	0.096		
		1987.7621	85.4	0.103		
ADS 14783	H 48				202582	21137+6425
		1986.8856	257.7	0.346		
ADS 14784	STF 2783				202519	21141+5818
		1986.8856	4.8	0.757		
		1987.7565	4.9	0.755		

TABLE II. (continued)

ADS 14773	STT 535 AB				202275	21146+1001
		1986.8910	211.1	0.112		
		1987.7592	111.5	0.032		
		1987.7621	104.2	0.034		
ADS 14798	A 1692				202642	21152+5531
		1987.7565	157.6	0.326		
ADS 14824	A 401				202810	21171+4312
		1987.7566	142.2	0.424		
+30°4393	Cou 1183				202882	21180+3049
		1987.7540	25.6	0.229		
ADS 14839	Bu 163 AB				202908	21187+1134
		1986.8910	76.4	0.061		
		1987.7593	58.0	0.056		
ADS 14864	STF 2790 Aa				203338	21192+5837
		1986.8911	118.6	0.103		
		1987.7593	120.0	0.100		
ADS 14876	A 1695				203379	21199+5319
		1986.8856	198.4	0.475		
ADS 14879	A 295				203302	21206+2743
		1986.8856	243.7	0.360		
ADS 14893	A 617				203345	21214+1021
		1986.8910	108.2	0.121		
		1987.7539	100.8	0.162		
		1987.7593	98.7	0.163		
ADS 14944	A 765 AB				203938	21238+4710
		1986.8856	28.1	0.443		
ADS 14954	Bu 164 AB				203943	21251+0923
		1987.7539	207.6	0.163		
		1987.7593	207.4	0.161		
+28°4085	Cou 940				204051	21253+2928
		1986.8856	274.7	0.331		
		1987.7539	274.8	0.337		
ADS 14960	A 2289 AB				203993	21255+0203
		1987.7539	22.4	0.088		
HR 8238	β Cep Aa				205021	21288+7034
		1986.8910	52.5	0.100		
		1987.7593	55.1	0.090		
ADS 15058	A 771				205085	21316+4817
		1986.8911	54.8	0.058		
HR 8245	CHARA 102				205314	21329+4959
		1986.8911	84.8	0.048		
		1987.7593	100.9	0.047		
ADS 15115	Hu 371				205541	21354+2427
		1987.7539	300.0	0.301		
ADS 15131	Ho 463				205731	21362+4253
		1986.8856	174.9	0.455		
ADS 15176	Bu 1212 AB				206058	21395−0003
		1987.7539	254.5	0.445		
+08°4714	CHARA 105				206155	21400+0911
		1987.7539	97.2	0.257		
ADS 15236	Hu 280				206512	21423+0554
		1987.7539	141.5	0.204		
HR 8300	Kui 108				206644	21425+4106
		1986.8911	21.0	0.199		
		1987.7540	16.2	0.202		
ADS 15251	Bu 688 AB				206656	21426+4103
		1986.8856	203.9	0.348		
		1987.7540	203.5	0.354		
ADS 15281	Bu 989 AB				206901	21446+2539
		1986.8938	115.3	0.269		
		1987.7593	109.7	0.261		
ADS 15315	Hu 970				207369	21455+6745
		1986.8857	273.9	0.359		
ADS 15339	Hu 971 AB				207577	21478+6203
		1986.8857	200.2	0.305		
+34°4540	Cou 1484				207663	21498+3455
		1986.8856	354.0	0.360		
HR 8344	Cou 14				207652	21502+1718
		1986.8938	53.3	0.311		
		1987.7621	59.7	0.272		
ADS 15375	Ho 170				207782	21505+3925
		1986.8856	239.6	0.317		
ADS 15435	A 620				208341	21540+4403
		1986.8856	278.4	0.342		
ADS 15499	Bu 275				208905	21573+6117
		1986.8857	171.1	0.422		
ADS 15530	Hu 774				209103	21598+4908
		1987.7593	145.1	0.178		
ADS 15578	Bu 694 AB				209515	22030+4439
		1986.8857	4.4	0.960		
ADS 15599	Bu 696 AB				209622	22045+1552
		1987.7594	5.5	0.150		
ADS 15615	Hu 977				—	22048+6539
		1986.8857	312.3	0.278		
ADS 15613	A 1453				—	22054+3858
		1986.8856	325.3	0.527		
ADS 15633	A 183				—	22059+4522
		1986.8857	244.8	0.735		
+25°4677	Cou 537				—	22077+2622
		1986.8856	41.3	0.166		
ADS 15670	STF 2872 BC				210432	22086+5918
		1986.8857	301.4	0.830		
ADS 15726	A 625 AB				210875	22117+5743
		1986.8857	73.9	0.501		
ADS 15748	A 626				239892	22127+6013
		1986.8857	101.9	0.748		
ADS 15746	Hu 695				—	22129+5058
		1986.8857	15.1	0.837		
+43°4153	Cou 1829				—	22131+4437
		1986.8857	114.4	0.178		
ADS 15756	Bu 991				211113	22136+5234
		1986.8857	137.9	0.682		
ADS 15794	Ho 180				211405	22158+4354
		1986.8857	237.0	0.755		
+16°4707	Hei 192				211542	22175+1649
		1987.7594	145.2	0.140		
ADS 15846	A 185				—	22201+4625
		1986.8857	313.0	0.779		
ADS 15867	A 411				212153	22214+4148
		1986.8857	223.2	0.284		
+42°4396	Cou 1986				—	22263+4308
		1986.8857	10.8	0.448		
+39°4837	Cou 1642				212900	22268+4034
		1987.7594	75.9	0.155		
ADS 16011	Hu 981				213530	22306+6138
		1986.8857	221.4	0.319		
+17°4759	Cou 234				213392	22307+1758
		1987.7594	317.5	0.153		
+53°2911	Kui 112 Aa				—	22327+5347
		1986.8857	231.5	0.609		
ADS 16057	STF 2924 AB				213973	22329+6954
		1986.8857	93.4	0.392		
ADS 16072	Hu 983				214051	22339+6550
		1986.8911	220.8	0.068		
ADS 16073	A 1468				213990	22342+5405
		1986.8911	254.1	0.274		
ADS 16098	A 1470				214222	22357+5312
		1986.8911	300.8	0.103		
ADS 16095	CHARA 112 Aa				214168	22359+3938
		1986.8885	128.7	0.044		
		1987.7594	134.0	0.045		
ADS 16111	Bu 1092 AB				214511	22361+7252
		1986.8911	235.9	0.221		
HR 8617	CHARA 114				214558	22383+4511
		1986.8911	126.6	0.110		
		1987.7622	133.7	0.104		
ADS 16138	Ho 295				214608	22387+4418
		1986.8911	334.5	0.321		
+80°0731	McA 72				215319	22394+8123
		1986.8911	98.7	0.152		
ADS 16164	Ho 188				214807	22402+3731
		1986.8885	203.3	0.341		
HR 8629	Kui 114				214810	22408−0333
		1986.8884	125.5	0.236		
		1987.7622	126.4	0.264		
ADS 16173	Ho 296 AB				214850	22408+1432
		1986.8884	82.0	0.320		
		1987.7622	77.3	0.369		
ADS 16214	STT 476 AB				215242	22431+4709
		1986.8911	304.8	0.497		
ADS 16214	Hu 91 BC				215242	22431+4709
		1986.8911	51.4	0.046		

TABLE II. (continued)

ADS 16249	Hu 783				215590	22453+5128
		1986.8911	182.6	0.204		
ADS 16314	Ho 482 AB				216285	22514+2624
		1986.8884	32.6	0.378		
HR 8704	McA 73				216494	22535−1137
		1986.8884	289.2	0.079		
ADS 16380	A 416				—	22563+4247
		1986.8911	342.7	0.383		
HR 8762	o And AB				217675	23019+4219
		1986.8911	353.4	0.258		
		1987.7622	352.7	0.249		
ADS 16457	A 194				217712	23020+4800
		1986.8912	291.3	0.140		
+63°1917	Mlr 69				217848	23024+6413
		1986.8914	116.6	0.287		
ADS 16467	Bu 1147 AB				217782	23026+4245
		1986.8912	340.2	0.398		
ADS 16497	A 417 AB				218060	23052−0742
		1986.8912	31.8	0.193		
		1987.7622	41.4	0.202		
ADS 16505	A 196				218196	23055+4643
		1986.8912	314.7	0.473		
ADS 16518	Bu 180 AB				218439	23072+6049
		1987.7568	143.3	0.577		
ADS 16530	Hu 994				218537	23078+6338
		1986.8914	309.7	0.215		
		1987.7568	310.4	0.220		
HR 8817	Rst 3320				218640	23099−2227
		1986.8912	305.9	0.246		
ADS 16561	Bu 385 AB				218767	23103+3228
		1986.8912	91.5	0.644		
ADS 16576	Ho 197 AB				218917	23115+3813
		1986.8912	313.2	0.311		
		1987.7567	313.4	0.316		
ADS 16591	A 2298				219018	23126+0242
		1986.8912	96.5	0.129		
ADS 16610	A 1481				—	23137+3931
		1987.7567	170.8	0.198		
ADS 16621	A 200				219334	23147+4116
		1987.7567	79.9	0.546		
+00°4982	CHARA 141				219420	23157+0119
		1986.8912	38.5	0.061		
ADS 16638	Bu 992				219633	23164+6408
		1986.8914	41.1	0.272		
		1987.7568	37.6	0.275		
ADS 16650	Hu 400				219675	23176+1819
		1986.8912	122.9	0.344		
		1987.7567	122.0	0.344		
+27°4530	Cou 439				219963	23199+2846
		1986.8912	214.2	0.216		
		1987.7567	218.9	0.219		
+33°4690	Cou 742				219982	23199+3444
		1986.8912	26.8	0.268		
		1987.7567	28.0	0.270		
+15°4809	Hei 88				220077	23209+1643
		1987.7567	213.8	0.250		
ADS 16708	Hu 295				220278	23226−1503
		1986.8912	113.6	0.253		
+34°4915	Cou 1346				—	23239+3456
		1987.7567	84.8	0.232		
ADS 16731	STT 495				220562	23241+5732
		1986.8912	119.8	0.307		
		1987.7567	120.6	0.310		
ADS 16748	Ho 489 AB				220723	23259+2742
		1986.8912	226.6	0.541		
		1987.7567	226.2	0.541		
+22°4835	Cou 338				220794	23266+2342
		1986.8912	41.1	0.105		
ADS 16760	A 1485				220869	23268+5434
		1986.8912	212.2	0.575		
		1987.7567	212.8	0.558		
ADS 16800	Bu 1266 AB				221264	23305+3050
		1986.8885	77.1	0.261		
		1987.7567	75.1	0.259		
+18°5163	Cou 340				—	23322+1942
		1987.7567	61.2	0.262		
ADS 16819	Hu 298				221445	23322+0705
		1986.8885	166.8	0.119		
+22°4860	Cou 144				—	23339+2342
		1987.7567	55.2	0.338		
ADS 16836	Bu 720				221673	23340+3120
		1986.8939	264.0	0.523		
		1987.7567	264.9	0.524		
ADS 16858	Bu 721 AB				221925	23363−0707
		1986.8912	134.4	0.251		
ADS 16873	Fox 102 AB				222068	23374+0737
		1987.7566	311.7	0.232		
ADS 16877	STT 500 AB				222109	23375+4426
		1986.8914	358.9	0.494		
		1987.7567	359.6	0.495		
ADS 16904	A 643				222326	23392+4543
		1986.8914	156.4	0.225		
		1987.7540	155.2	0.229		
+45°4301	Mlr 4				222516	23412+4613
		1986.8885	316.1	0.105		
ADS 16928	Bu 858 AB				222529	23413+3234
		1987.7568	229.4	0.828		
HR 9003	McA 75 Aab				223047	23460+4625
		1987.7540	101.9	0.296		
		1987.7622	102.9	0.299		
ADS 16995	Bar 19				223139	23470+0515
		1987.7566	0.4	1.077		
+35°5106	Cou 944				—	23485+3608
		1987.7540	95.8	0.194		
ADS 17019	B 2547 AB				223331	23485+3617
		1986.8885	360.0	0.236		
		1987.7540	1.5	0.234		
ADS 17020	STT 507 AB				223358	23486+6453
		1986.8914	307.6	0.732		
		1987.7568	307.9	0.724		
ADS 17030	A 424				223486	23498+2740
		1986.8885	113.1	0.169		
		1987.7542	113.8	0.168		
ADS 17036	A 792				—	23505+4703
		1987.7540	265.4	0.702		
ADS 17039	A 793				—	23506+4705
		1986.8914	129.3	0.126		
ADS 17050	STT 510 AB				223672	23516+4205
		1986.8914	305.3	0.548		
		1987.7540	305.5	0.551		
HR 9041	Fin 359				223825	23529−0313
		1986.8885	351.1	0.040		
		1987.7622	322.8	0.042		
+42°4792	Cou 1498				224167	23557+4318
		1986.8885	36.8	0.174		
		1987.7540	37.0	0.179		
ADS 17104	Hu 500				224219	23561+2327
		1987.7542	89.4	0.171		
ADS 17111	A 2100				224315	23568+0443
		1986.8885	155.6	0.132		
-14°6588	Rst 4136 AB				224512	23586−1408
		1986.8912	22.3	0.178		
ADS 17151	A 1498				224646	23594+5441
		1986.8914	83.9	0.388		
		1987.7540	84.3	0.389		

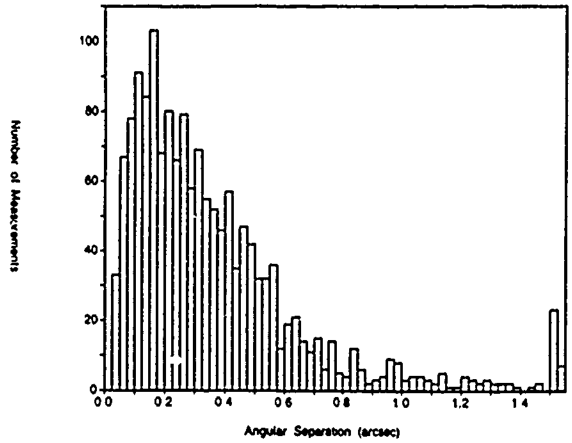

FIG. 2. The distribution of measured angular separations from Table II is shown. Separations range from 0.031 to 2.91 arcsec, with mean and median values of 0.372 and 0.285 arcsec, respectively, for the 1550 measures of 1006 systems.

II is 0.372 arcsec, while the median value is 0.285 arcsec. A histogram of the measured angular separations is shown in Fig. 2. The limiting magnitude of our system is currently determined by the detector properties and by the thresholding properties of the hardwired vector autocorrelator (VAC). The microchannel plate intensifier is showing a very strong loss of sensitivity over the region typically illuminated by speckle patterns, a degradation amounting to nearly a factor of 3 decrease in sensitivity relative to the edge of the tube. The CCD itself shows a rather strong fixed pattern that correlates randomly with each event tagged by the VAC so that the noise contribution to autocorrelograms is increased and, in the faint limit, prohibits application of this detector in a sparse, single photon domain. We expect to replace the detector during 1989 and to immediately retire the VAC in favor of a commercially available frame-grabber board operating in conjunction with efficient software on a PC/AT type computer.

As opportunities arose from well-observed portions of the primary program, we obtained data for the 293 stars from *The Bright Star Catalogue* (Hoffleit 1982) that are listed in

TABLE III. Bright stars inspected for duplicity.

HR	HR	HR	HR	HR	HR	HR	HR
1	135	4052	4184	4351	4629	5388	5581
4	144	4054	4187	4357	4632*	5392	5588
7	146	4057	4191	4358	4633	5394	5589
8	153	4062	4195	4359	4641	5402	5596
15	603	4064	4202	4362	4642*	5405	5608
17	620	4067	4203	4366	4643	5411	5609
19	1593	4070	4215	4371	4650	5414	6039
21	1594	4072	4232	4378	4654	5415	6047
26	1603	4075	4235	4380*	4659	5416	6057
27	1622	4077	4236	4381	4663	5420	6065
28	1623	4078	4241	4386	4666	5422	6068
36	1624	4079	4243	4528*	4667	5423	6087
38	1644	4081	4246	4533	4672	5424	6093
39	1647	4084	4248	4535	4673	5430	6095
40†	1668	4085	4256	4536	4676	5434	6107
41	1675	4088	4258	4543	5317	5436	6108
44	1678	4090	4259	4545	5330	5437	6111
45	4004	4096	4260	4555	5331	5441	6152
49	4006	4097	4265	4559	5333	5442	6154
50	4008	4103	4267	4560†	5335	5445	6159
52	4012	4106	4269	4561	5343	5448	6176
53	4014	4108	4270	4562	5345	5451	9078
56	4016	4113	4277	4564	5346	5452	9079
60	4021	4121	4278	4566	5347	5464	9080
62	4024	4124	4281	4569	5350	5467	9083
63*	4026	4126	4285	4572	5351	5468	9085
65	4027	4127	4288	4574	5352	5479	9086
70	4030	4131	4294	4575	5360	5492	9092
75	4032	4137	4300	4580	5363	5493	9093
76	4035	4141	4309	4581	5365	5510	9097*
82	4039	4150	4310	4584	5369	5529	9100
93	4041	4165	4319	4585	5370	5533	9105*
96	4044	4166	4322	4593	5372*	5537	9109
104	4046	4168	4332	4594	5373	5541	9110
113	4047	4176	4333	4602	5374	5552	
124	4048	4178	4341	4610	5384	5563	
128	4051	4181	4345	4626	5387	5569	

Stars with HR numbers less than 2000 or greater than 9000 were observed during November 1986, the remaining *Bright Stars* were observed during April 1987. Asterisks indicate those stars for which new companions have been discovered, as reported in Table I. Daggers indicate known binaries, listed in Table II under their ADS designations (HR 40 = ADS 161, HR 4560 = ADS 8347).

Table III. We are continuing the survey of bright stars begun in Paper I as observing time permits at the Mayall telescope and by follow-up runs at the 3.6 m Canada–France–Hawaii telescope on Mauna Kea. The second CFHT run occurred in February–March 1988; the results will be published as a continuation to Paper I. Our approach in this long-term effort is to use only times of good seeing that are available, after the primary programs have been observed at Kitt Peak, and to employ the intermediate magnification of 0.0088 arcsec per pixel along with the Strömgren *y* bandpass. At the Mayall telescope, the survey is defined by a rectangular box centered upon the bright star with a north–south dimension of 2.25 arcsec and an east–west dimension of 1.13 arcsec. As in Paper I, we consider our approach capable of detecting angular separations down to the diffraction limit of 0.035 arcsec, with the further condition that the magnitude difference does not exceed about 2 mag. Eight new binary stars, for which identifications are listed in Table I, were discovered in the sample of stars listed in Table III. The lower discovery frequency here compared with the results from the CFHT in Paper I is consistent with the prevalence of evolved stars over dwarfs in this newest sample, in which no preference was made for dwarfs, in constrast to the selection of candidates in Paper I.

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BINARY STAR ORBITS FROM SPECKLE INTERFEROMETRY. I. THE HYADES BINARY FINSEN 342 (70 TAURI)

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ABSTRACT

We test the conclusion of Peterson and Solensky (1987) that the motion of the Hyades binary Finsen 342 is best represented by a 6 yr eccentric orbit rather than by a 13 yr circular orbit assumed in most previous analyses. Through the digital processing of four sets of speckle observations obtained between 1975 and 1986 to unambiguously determine the quadrant of the secondary star at those epochs, we show conclusively that the orbit is indeed the short-period one, with a period of 6.264 yr. A new orbital solution, based solely upon speckle coverage of two revolutions, is shown to give an overall better fit to all the available visual, occultation, and interferometric data than any previously determined orbit for Fin 342, even though we exclude visual and occultation observations from the orbital solution. An initial estimate of the magnitude difference is determined from the speckle observations.

I. INTRODUCTION

The orbit of the Hyades binary star Fin 342 (70 Tauri = HR 1391 = HD 27991: R.A. = 4^h26^m, Dec. = + 15°57′, for equinox 2000) has presented the possible ambiguity of long period, low eccentricity versus short period, high eccentricity since shortly after the duplicity of the star was discovered by William S. Finsen in 1959. The subsequent history of the system's measurement by visual interferometry and micrometry, by lunar occultation observations, and by speckle interferometry has been extensively reviewed by Peterson and Solensky (1987, hereafter referred to as PS), who argue the short-period case for the system, a possibility first suggested by Eggen (1963) on the basis of the inordinately small masses resulting from the 13 yr period. PS present the results of a period search showing that a 6 yr period is as acceptable to the data as the 13 yr period found by Finsen (1978) in his final analysis of the observational material, most of which at that time had been accumulated by him. PS support their conclusion by presenting spectroscopic data obtained photographically at the Kitt Peak coudé-feed telescope and spectrograph. Their spectrograms never resolved the lines from the individual components, but the blended line profiles were judged by inspection to be broader at the epoch of maximum velocity separation predicted by the 6 yr orbit. On the basis of this highly suggestive evidence, PS adopt the 6 yr period, calculate the elements of the visual orbit, and reanalyze McClure's (1982) deduction of the Hyades' distance modulus.

Another suggestive piece of evidence against the longer period can be seen from simple inspection of the speckle observations plotted against the elliptical orbit. In Fig. 1, we show the speckle measures along with the 12.51 yr orbit recently published by Couteau (1987). Arrows in Fig. 1 indicate three speckle measures with epochs of 1975.716, 1982.766, and 1982.847 that have very large negative residuals in angular separation, residuals that are nearly an order of magnitude greater than would be expected from speckle data. The observed motion, when the longer period is assumed, has a very pinched appearance about an axis passing through these three measures. This suggests that the axis of the pinch in the motion might define a line about which approximately half of the data should be given 180° position-angle projections. It is also interesting to note in Fig. 1 that the position angles of the visual measures, including the visual interferometer observations of Finsen, tend to generally avoid the axis of the apparent "pinch" in the speckle observations.

The goal of this study is to finally lay to rest the controversy surrounding the orbital period of Fin 342 by definitively establishing the true quadrant of the secondary at critical orbital epochs. Through the analysis of four sets of speckle observations obtained at the Kitt Peak 4 m telescope during 1975–1976 and 1985–1986, we conclusively settle the issue of the true orbital period of this important Hyades binary.

II. THE SPECKLE OBSERVATIONS

Fin 342 was observed by the first author during his first speckle observing run at the Kitt Peak 4 m telescope in September 1975 and continues to be a high-priority object on the GSU/CHARA program of binary star speckle interferometry. The system has now been observed at some 23 epochs by us with an additional six observations from other speckle observers. The collected speckle measurements are presented in Table I, where the position angles have been precessed to the equinox for 2000.0. The small corrections to the GSU/CHARA observations between 1982 and 1985 discussed by McAlister *et al.* (1988, in preparation) have been included in the measures in Table I. The coverage fails to complete one long-period orbital cycle by just under one month and is just five days short of encompassing two of the short-period cycles.

PS calculated the orbital elements given in Table II for the

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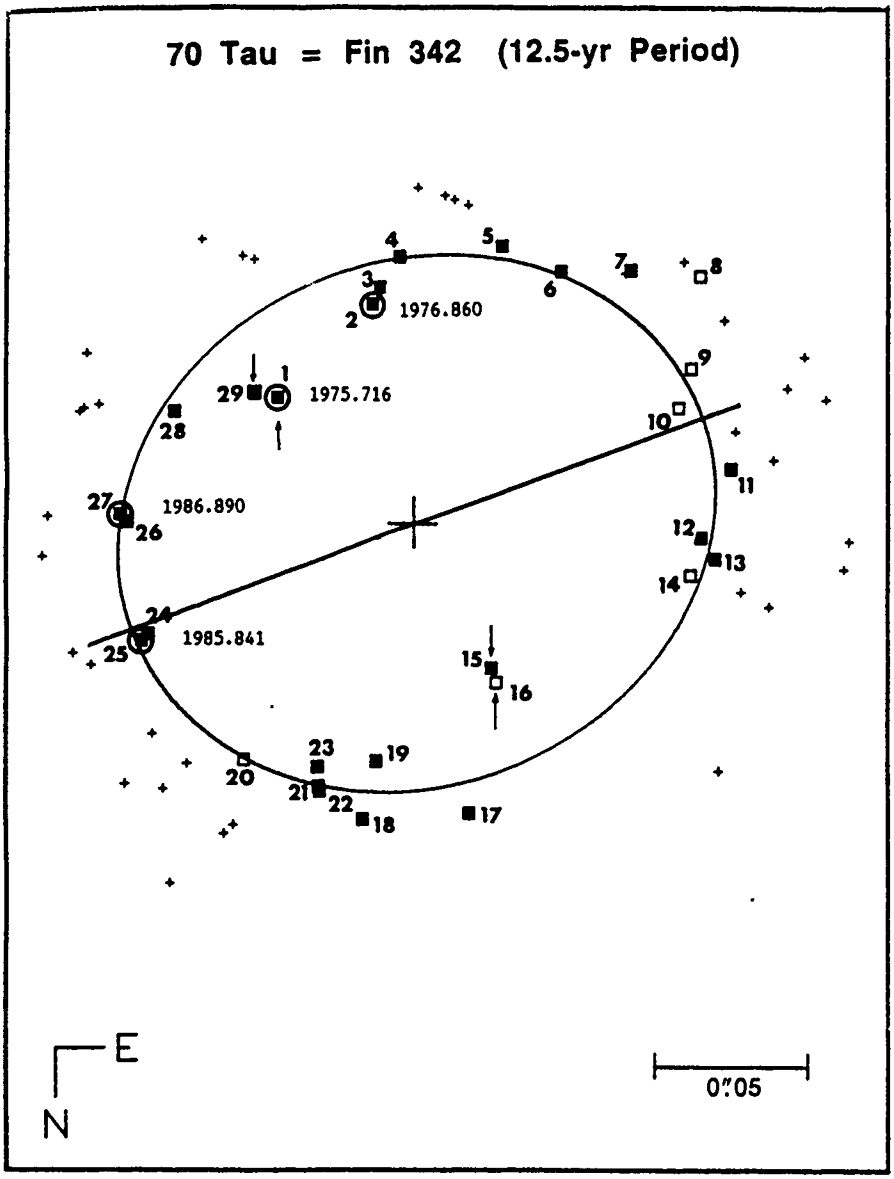

FIG. 1. The collection of existing measurements of Finsen 342 is shown here, where plus signs represent the visual interferometer measures of W. S. Finsen and the visual micrometer measures of van den Bos, Couteau, and Morel. Dark squares are those speckle observations from the GSU/CHARA program, while light squares are from other modern interferometric programs. Each speckle data point is identified by the observation number from Table I. Also shown here is the line of nodes for which the identification of the true ascending node remains ambiguous. Quadrants are adopted here in order to be consistent with a presumed long-period orbit. The orbit of Couteau (1987) for a 12.51 yr period is shown against these measurements. The speckle observations for which true quadrant determinations have been made are circled. Of these, only the measure for 1976.860 does not require a quadrant reversal. The "pinched" appearance of the data when plotted against the long-period orbit is apparent in the observations shown with arrows and indicates rather clearly where the possible 180° position-angle reversals could yield a plausible 6 yr orbital motion.

6, 9, and 13 yr periods found in their period search. The quadrants adopted for the position angles in column 3 of Table I are based upon the 13 yr orbit and are consistent with the quadrants determined from occultation observations. Superscripts next to the position angles in Table I indicate quadrant reversals as called for by the three possible periods found by PS. We also include in Table II the elements determined by Finsen (1978), Evans (1984), and Couteau (1987). The residuals to these elements are listed in Table III.

The 9 yr orbit is obviously inappropriate to the observations, showing position-angle residuals of 90° for the most recent speckle observations not available to PS. The 13 yr orbit (solution I of PS) shows average residuals and their rms dispersions of $\langle\Delta\theta\rangle = +5.0° \pm 7.0°$ and $\langle\Delta\rho\rangle = -0.001 \pm 0.011$ arcsec, while the 6 yr orbit (solution III of PS) leads to $\langle\Delta\theta\rangle = +5.5° \pm 7.2°$ and $\langle\Delta\rho\rangle = +0.004 \pm 0.009$ arcsec. The dispersions in the residuals do not favor either of these two solutions over the other, and both solutions show systematic effects in the position-angle residuals. The 13 yr orbit of Couteau (1987) does a better job of fitting the position angles with comparable dispersion in the separation residuals to the orbits of PS.

As has been pointed out by Evans (1984), the speckle angular separations are all systematically smaller than the separations obtained by Finsen with his eyepiece interferometer, and we would thus expect that the orbit of Finsen would not represent these modern measures at all well. Indeed, the average residuals of the GSU/CHARA speckle measures to the elements determined by Finsen (1978) are $\langle\Delta\theta\rangle = -14.1 \pm 12.7$ and $\langle\Delta\rho\rangle = -0.026 \pm 0.009$. In his important revision of the Hyades distance modulus, McClure (1982) recognized the discrepancy between Finsen's observations and the modern results, but he considered Fin 342 as providing one of the best mass determinations of the Hyades visual binaries. In the correspondence between Finsen and one of us (HM) during the years preceding Finsen's death in 1979, it is clear that Finsen considered this last orbit as being short of definitive, and he was keenly interested in seeing continued speckle coverage of this system. It is

TABLE I. Speckle observations.

Speckle Obs. No.	Epoch 1900.0 +	θ	ρ	Source
1	75.716	228.3^{6}	0.060	GSU
2	76.860	190.8	0.071	GSU
3	76.923	188.1	0.076	GSU
4	77.087	182.9	0.085	GSU
5	77.742	161.6	0.093	GSU
6	78.149	148.6	0.094	GSU
7	78.618	138.3	0.108	GSU
8	78.876	129.7	0.123	(1)
9	79.857	118.1	0.104	(2)
10	79.926	112.6	0.095	(2)
11	80.153	99.2	0.106	GSU
12	80.729	87.1	0.095	GSU
13	80.882	83.4	0.100	GSU
14	80.939	79.6	0.093	(3)
15	82.766	29.0^{6}	0.053	GSU
16	82.847	28.5^{6}	0.058	(4)
17	83.047	11.2^{6}	0.095	GSU
18	83.711	350.1^{6}	0.097	GSU
19	83.714	351.1^{6}	0.078	GSU
20	83.934	323.6^{6}	0.094	(5)
21	84.052	339.8^{6}	0.090	GSU
22	84.058	340.3^{6}	0.092	GSU
23	84.060	338.1^{6}	0.085	GSU
24	85.838	292.2^{6}	0.094	GSU
25	85.841	293.0^{6}	0.097	GSU
26	86.886	269.8^{6,9}	0.094	GSU
27	86.890	268.4^{6,9}	0.096	GSU
28	87.766	245.5^{6,9}	0.087	GSU
29	88.165	230.9^{6,9}	0.066	GSU

Notes to TABLE I

Superscripts indicate quadrants to be reversed in considering alternative periods of 6 and 9 yr. All position angles have been precessed to equinox 2000.0.

Sources: GSU—from catalog of McAlister and Hartkopf (1988)

(1)—Morgan *et al.* (1982)
(2)—Hege *et al.* (1981)
(3)—Ebersberger *et al.* (1986)
(4)—Tokovinin (1983)
(5)—Bonneau *et al.* (1984)

therefore particularly pleasing to present such coverage at the present time.

III. THE QUADRANT AND MAGNITUDE-DIFFERENCE ANALYSIS

PS point out that the confusion with regard to the true orbital period of Fin 342 would be easily set aside were it not for the 180° position-angle ambiguity inherent in speckle interferometry. They urge speckle observers to take the next step by modifying reduction algorithms in such a way as to eliminate this ambiguity, a sentiment with which we are in complete accord. It should be emphasized, however, that the step from simple autocorrelation analysis of speckle data to analyses that effectively reconstruct a diffraction-limited image of the binary star in question is far from trivial. The astrometry that has been published from the GSU/CHARA speckle program has been performed using a hardwired vector-autocorrelator (VAC) that gives a 1 bit (on/off) digitization of two-dimensional speckle frames. The VAC then calculates a histogram of all separations among the sample of "on" pixels, an operation that can be quickly carried out in hardware, and provides autocorrelograms from which the relative positions of the two components can be accurately extracted, albeit with the quadrant ambiguity inherent in this process.

In order to eliminate this ambiguity, and even more importantly, to determine the magnitude difference in the system, it is necessary to digitize each speckle frame to at least 6 bits and preferably to 8 bits in intensity. High-speed digitizer boards are now available at modest cost for microcomputers that give 8 bit digitization with 512×512 pixel frames at video frame rates. The real bottleneck in the processing of these data, coming in from the speckle camera at a potentially prodigious rate of 62 megabytes per second, is the implementation of the several possible algorithms to reconstruct the binary star image at a rate sufficiently efficient so as not to waste telescope time. The augmentation of these methods for routinely processing high volumes of speckle data for bright objects is far from being a simple extension of current methods. Fortunately, of the nearly 1500 binary stars on our program, no more than 20 suffer from the ill effects of quadrant ambiguity, as the great majority of our program stars are visual binaries with quadrants unambiguously determined by the visual observers or are spectroscopic binaries with existing orbits.

The most pressing justification for introducing new techniques for processing binary star speckle data lies with the essentially complete absence of accurate photometry for the individual components of close visual binary stars. Nevertheless, the occasional problem presented by such systems as Fin 342 is a fascinating challenge to speckle observers. It might also be pointed out that the quadrant ambiguity in this system would not exist if its angular separation were somewhat larger than the maximum it presents of just over 0.10 arcsec. The classic quadrant-ambiguity case holds for visual binaries with zero magnitude differences (see Heintz 1978), but Fin 342 has been shown from occultation observations to have a magnitude difference of about 0.4 mag. If the star could be explicitly resolved by visual observers, then the quadrant problem would have been eliminated. Indeed, if the magnitude difference were really zero, then speckle methods could not be used to settle the issue. It is also interesting to reiterate the opinion of the eminent double star observer W. H. van den Bos (as privately communicated to

TABLE II. Published orbits for Fin 342.

	Finsen (1978)	Evans (1984)	Couteau (1987)	Peterson and Solensky (1987) I	Peterson and Solensky (1987) II	Peterson and Solensky (1987) III
P (yr)	13.15	11.4	12.51	12.54	9.48	6.045
T (BY)	1962.84	1976.3	1986.52	1981.956	1974.750	1976.250
a (arcsec)	0.133	0.108	0.100	0.1001	0.0827	0.0941
e	0.073	0.073	0.01	0.066	0.280	0.701
i	132.6	132.6	146.9	138.5	152.0	127.0
ω	97.1	90.1	14.6	243.3	281.9	91.6
node	321.4	310.1	289.0	284.5	219.7	33.8
$a^3/P^{2\,a}$	0.60	0.43	0.28	0.29	0.28	1.00

[a] Normalized to unity for PS orbit III.

TABLE III. Speckle residuals to published orbits.

Speckle Obs. No.	Finsen (1978)	Evans (1984)	Couteau (1987)	Peterson and Solensky (1987) I	II	III	New Speckle Orbit	Final Weight
1	-5.4 -0.024	-21.6 -0.013	-0.9 -0.026	+0.8 -0.026	-5.4 -0.007	-1.8 -0.006	+3.5 -0.003	1
2	+5.0 -0.028	-0.3 -0.002	+0.5 -0.013	+0.4 -0.008	+1.8 -0.011	-0.6 +0.002	-0.2 -0.002	1
3	+4.3 -0.024	-0.1 +0.002	-0.1 -0.008	-0.1 -0.003	+1.2 -0.007	-0.4 +0.005	-0.2 +0.001	1
4	+4.3 -0.019	+1.9 +0.008	+0.2 +0.000	+0.3 +0.005	+1.1 +0.001	+1.2 +0.008	+1.0 +0.005	1
5	+0.2 -0.026	+3.7 +0.001	-0.1 +0.004	+0.3 +0.010	-0.7 +0.005	+1.0 +0.004	+0.6 +0.003	1
6	-4.0 -0.032	+1.7 -0.006	-1.2 +0.001	-0.6 +0.007	-2.4 +0.004	-0.8 +0.002	-1.1 +0.000	1
7	-5.0 -0.023	+2.4 +0.002	+1.1 +0.012	+1.7 +0.016	-0.2 +0.016	+1.0 +0.013	+0.8 +0.012	1
8	-8.7 -0.009	-0.5 +0.016	-0.9 +0.025	-0.5 +0.029	-2.1 +0.031	-1.2 +0.027	-1.3 +0.025	0
9	-1.3 -0.022	+9.3 +0.000	+11.1 +0.003	+10.8 +0.007	+10.9 +0.009	+11.2 +0.008	+10.7 +0.004	0
10	-5.4 -0.030	+5.4 -0.008	+7.2 -0.006	+6.8 -0.002	+7.1 +0.000	+7.4 -0.001	+6.8 -0.005	0
11	-14.0 -0.016	-2.6 +0.006	-0.8 +0.006	-1.3 +0.010	-0.7 +0.011	-0.5 +0.010	-1.2 +0.006	1
12	-12.5 -0.018	+1.0 +0.004	+1.2 -0.003	+0.6 +0.003	+1.3 +0.001	+2.1 +0.003	+0.6 -0.002	1
13	-12.2 -0.010	+2.0 +0.011	+1.4 +0.003	+0.9 +0.010	+1.4 +0.006	+2.5 +0.009	+0.8 +0.004	1
14	-14.4 -0.017	+0.1 +0.005	-0.9 -0.003	-1.4 +0.004	-1.0 -0.001	+0.3 +0.003	-1.6 -0.002	1
15	-5.2 -0.046	+18.6 -0.031	+4.0 -0.031	+14.2 -0.017	+2.7 -0.021	+10.3 -0.009	-2.8 -0.000	1
16	-3.0 -0.042	+20.9 -0.027	+6.3 -0.026	+17.2 -0.013	+5.4 -0.015	+14.2 -0.008	+2.7 -0.001	1
17	-13.8 -0.007	+10.3 +0.007	-4.2 +0.011	+8.4 +0.024	-3.1 +0.026	+6.1 +0.021	-3.3 +0.025	0
18	-16.0 -0.015	+8.4 -0.002	-3.1 +0.011	+13.0 +0.018	+14.1 +0.041	+7.3 +0.009	+0.3 +0.010	1
19	-14.9 -0.034	+9.4 -0.021	-2.0 -0.008	+14.1 -0.001	+15.3 +0.022	+8.4 -0.010	+1.4 -0.009	1
20	-35.9 -0.022	-12.6 -0.007	-22.5 +0.006	-6.1 +0.012	+4.0 +0.041	-12.9 +0.004	-19.5 +0.004	0
21	-17.9 -0.028	+6.5 -0.013	-2.6 +0.002	+13.8 +0.006	+29.5 +0.037	+6.6 -0.001	+0.1 -0.001	1
22	-17.2 -0.026	+7.1 -0.012	-1.0 +0.003	+14.5 +0.008	+30.4 +0.039	+7.2 +0.001	+0.8 +0.001	1
23	-19.4 -0.033	+5.0 -0.019	-4.0 -0.004	+12.4 +0.001	+28.4 +0.032	+5.1 -0.006	-1.3 -0.006	1
24	-30.3 -0.040	-1.3 -0.006	-2.0 -0.005	+8.8 -0.009	+85.7 +0.017	+3.7 -0.002	-2.0 -0.006	1
25	-29.5 -0.037	-0.4 -0.003	-1.1 -0.002	-9.7 -0.006	+86.6 +0.020	+4.5 +0.001	-1.1 -0.003	1
26	-32.0 -0.027	+9.7 +0.017	+1.8 -0.002	+8.0 -0.006	-82.3 +0.008	+7.8 +0.003	+0.6 -0.004	1
27	-33.4 -0.025	+8.4 +0.019	+0.5 +0.000	+6.7 -0.004	-83.6 +0.010	+6.5 +0.005	-0.7 -0.002	1
28	-33.0 -0.014	+29.1 +0.018	+2.0 -0.003	+4.4 -0.004	-81.9 -0.003	+13.3 +0.018	+0.4 +0.002	1
29	-33.5 -0.026	+35.2 -0.005	-0.3 -0.021	+0.7 -0.021	-85.9 -0.026	+32.1 +0.030	+1.7 -0.002	1

Average Residuals with respect to data of non-zero weight:

	<Delta Theta>	<Delta Rho>
Finsen (1978)	-14.1 ± 12.7	-0.026 ± 0.009
Evans (1984)	+6.0 ± 11.3	-0.003 ± 0.013
Couteau (1987)	-0.0 ± 2.2	-0.005 ± 0.011
Peterson & Solensky(1987)		
Orbit I	+5.0 ± 7.0	-0.001 ± 0.011
Orbit II	-	+0.007 ± 0.018
Orbit III	+5.5 ± 7.2	+0.004 ± 0.009
New Speckle Orbit	+0.1 ± 1.5	-0.000 ± 0.005

us by C. E. Worley) that when one is confronted with the choice between a long-period, small-eccentricity orbit and a short-period, large-eccentricity orbit, the short period is more likely to be the valid one because truly circular orbits are rare among visual binaries.

Methods for performing binary star "speckle photometry" have been under extensive scrutiny and development at GSU/CHARA since 1985. Our goal has been to develop the capability for extracting differential magnitudes and colors from speckle frames of binary stars obtained with the ICCD speckle camera. A description of experiments carried out with simulated speckle data aimed at discriminating among the various methods appropriate to the problem is presented by Bagnuolo (1988). These methods include variations of the "shift-and-add" (SAA) method first proposed by Bates and Cady (1980) and modified by Bagnuolo (1982), the

"triple correlation" method of Weigelt and Wirnitzer (1983), and the "fork" algorithm of Bagnuolo (1988). Bagnuolo finds that his "fork" method is the most linear of the techniques across a large range of magnitude differences. Bagnuolo and Sowell (1988) have also applied the new algorithm to a high-precision determination of the Strömgren y and $(b-y)$ values for the individual components of the Capella system.

We selected the speckle-data samples for the four epochs 1975.716, 1976.860, 1985.841, and 1986.890 as being capable of discriminating between the long- and short-period orbits. The short-period orbit calls for a periastron passage and resulting quadrant reversal between 1975 and 1977, while the long-period orbit keeps the components in the same quadrant during this interval. Both orbits call for no quadrant change between the 1985 and 1986 observations, but the common quadrant is reversed for the two periods. The four sets of data permit 16 possible quadrant combinations, only four of which correspond to the two possible orbital periods. A further check on the validity of the deduced set of quadrants is provided by the comparison with the quadrants determined by the lunar occultation results, a comparison to be made later.

The datasets for 1975 and 1976 consisted of approximately 50 exposures in each set that were originally recorded on Tri-X film and subsequently contact printed on high-contrast copy film for analog reduction in the coherent image-processing system described by McAlister (1977). The original negative for the 1975 data could not be located, and the positive copy was used in its place. The two sets of exposures were scanned with the PDS microdensitometer of the Lowell Observatory with a format sufficient to provide five resolution elements across an Airy disk. The absolute north–south orientation was established for both film sets by locating wide visual binaries that had been observed on the same nights as Fin 342. The objects used have nonzero magnitude differences, and their true quadrants have long been established by visual observers.

The two more recent sets of speckle observations of Fin 342 consisted of 1800 images, recorded on VHS format video cassette tapes, taken with the GSU/CHARA ICCD speckle camera using the methodology described by McAlister *et al.* (1987). These data were digitized using a high-speed video-digitizing system based upon a Data Translation DT-2851 frame grabber board installed in a Wyse pc-286 personal computer with 8 MBytes of expanded memory. When an image is grabbed by the DT-2851 board, the central 256×256 pixel area is averaged in software to a 128×128 pixel array. This gives a resolution equal to the limiting resolution of the speckle-camera detector and, as in the case of the photographic data, amounts to approximately five resolution elements per Airy disk. Sets of 256 speckle images were digitized in this manner for the 1985 and 1986 observations. The absolute north–south orientation was determined in the same manner as with the earlier datasets.

The four sets of digitized speckle observations of Fin 342 were reduced using SAA and "fork" algorithms, with the input astrometry being provided by vector autocorrelation. Triple correlation analyses were also performed on the first two datasets. The two earlier observation sets yielded lower signal-to-noise because only 50 exposures were available for processing. Furthermore, the photometric nonlinearity of the photographic data served to compress the dynamic range in intensity so that the contrast in the SAA spots has decreased. In spite of these effects, it was obvious by inspection of the SAA results that the secondary star was in the first quadrant (i.e., northeast of the primary) in 1975 and the third quadrant (southwest of the primary) in 1976. The triple correlation and "fork" results confirmed this conclusion. A preliminary report of the results from the photographic data (Bagnuolo and Sowell 1986) mistakenly placed the secondary in the third quadrant for both epochs due to an error made by the first author of this paper in establishing the north–south orientation for the 1975 data. The nature of this error is well understood, and we now have no doubt that a quadrant reversal occurred between 1975 and 1976, a conclusion consistent only with the 6 yr orbital period.

The ICCD results clearly showed that the secondary was to the east of the primary during 1985–1986, a result consistent with the quadrant determinations from the earlier datasets only in the case of the 6 yr orbit. A summary of the SAA results for the four selected epochs is given in Table IV, in which the intensities of the SAA peaks are shown for the two possible position angles at each epoch. The peaks have been normalized to unity for the brighter peak.

The "fork" analysis of the ICCD data yielded a ratio of the intensity of the secondary star to that of the primary star equal to 0.73 ± 0.04, corresponding to a magnitude difference at Strömgren y of 0.34 ± 0.06 mag. The uncertainty in the magnitude-difference determination is limited by the absence of appropriate bias and flatfield data for the two epochs, and we suspect that saturation effects among the brightest speckles in the ICCD frames are tending to decrease the magnitude difference in the SAA and "fork" analyses. We therefore choose not to adopt the magnitude difference determined here, preferring to add its accurate determination to an ongoing speckle-photometry project involving all Hyades binaries within the reach of speckle interferometry. We note that our determination of the magnitude difference in the Fin 342 system is in good agreement with that of Hege *et al.* (1981), who found a value of 0.31 ± 0.02 mag at 5000 Å. The systematic effects that we suspect exist in the present determination of the magnitude difference by no means alter our conclusions with regard to the true quadrant occupied by the secondary star at the four epochs we have analyzed.

We thus find that the speckle interferometric observations of Fin 342 conclusively show that a quadrant reversal occurred between 1975 and 1976 and that a subsequent reversal must have occurred sometime between the second and third datasets in order to place the secondary east of the primary star as it was in the fall of 1975. The most likely time for the second reversal can be seen from simple inspection of the entire set of speckle measurements to be between the 1980.939 and 1982.776 observations, a period during which the system was not observed due to lost coverage resulting from the transition from photographic to digital speckle cameras. A second reversal during that time also turns out to be consistent with the 6 yr orbit solution we have determined.

TABLE IV. Shift-and-add peak intensities.

Epoch	Position-angle possibilities/SAA peak intensities[a]	
1975.716	48.3/1.00	228.3/0.78
1976.860	10.8/0.82	190.8/1.00
1985.841	112.3/1.00	292.3/0.87
1986.890	88.4/1.00	268.4/0.73

[a] Normalized to unity for the higher of the two peak intensities.

IV. THE ORBIT OF FINSEN 342

PS calculated orbits for the three periods that they found to be represented by the data, using the position angles from the visual interferometer and micrometer results along with the complete sets of occultation and speckle data. They calculated weights based upon published error estimates and assigned errors of $\pm 20°$ to the visually determined position angles. The visually measured separations were not included by PS in their orbit solutions, as they were considered to be significantly systematically large in comparison with occultation and speckle separations. This bias is no doubt due to the fact that Fin 342 is never completely resolved at the telescopes used by Finsen and the two micrometer observers (P. Couteau and P. Morel) who have measured the system. The very existence of these measures is testimony to the skill of the few visual observers who have ever detected the duplicity of Fin 342.

We chose to determine the orbit of Fin 342 based only upon the speckle observations. The speckle data now cover another half revolution compared to that available to PS, and are of uniformly high quality compared to the visual observations. We also believe that it cannot be established without doubt that the position angles determined by visual interferometry are not without systematic effects as are the separations. Rather than risk biasing the orbit by including data that are not well understood, we incorporated only the homogeneous and well-understood collection of speckle observations. An initial solution, in which all observations are given unit weight, is calculated using a grid-search routine around input values for P, T, and e in which the remaining four elements are determined by least-squares evaluation of the Thiele–Innes elements at each grid point. A second solution is then performed in which observations exhibiting residuals in excess of three standard deviations in either ρ or $\rho \times \Delta\theta$ are given zero weight. The grid search minimizes the variance in the residuals and continues until the stepsizes converge to some arbitrarily small value. The orbital elements for Fin 342 were calculated in this manner and are presented along with their error estimates in Table V, where the short-period orbital elements of PS are repeated for comparison. The residuals to the speckle observations from the newly determined orbital elements are given in Table III along with the weights assigned to the individual measurements in the final solution. The newly determined orbit is shown with the speckle observations in their correct quadrants in Fig. 2. An ephemeris of the expected motion during the next revolution is given in Table VI, in which we indicate the epochs of periastron and nodal passage, events that occur during the fall and early winter of 1988. It is expected that radial-velocity measurements and further speckle observations during those months will confirm the conclusions by us and by Peterson and Solensky (1987). A determination of the mass ratio at nodal passage would be an extremely valuable addition to the problems of the distance to the Hyades and the masses of its member stars.

The orbital period we find is some 0.22 yr, or 3.6% longer, and the semimajor axis is 3.4 mas, or 3.6% larger, than the corresponding values determined by PS. This results in a value for the total mass of the system at a given distance, given by a^3/P^2, approximately 3.6% greater than that indicated by the orbit of PS.

TABLE V. Elements of the short-period orbit.

	Peterson and Solensky (1987)—orbit III	Newly determined elements from speckle observations
P (yr)	6.045 ± 0.027	6.264 ± 0.025
T (BY)	1976.250 ± 0.057	1976.164 ± 0.017
a (arcsec)	0.0941 ± 0.0030	0.0975 ± 0.0008
e	0.701 ± 0.013	0.691 ± 0.009
i	127.0 ± 1.9	126.8 ± 0.4
ω	91.6 ± 1.5	93.4 ± 0.9
node	33.8 ± 3.7	36.5 ± 0.9
a^3/P^2 [a]	1.00 ± 0.10	1.036 ± 0.03

[a] Normalized to unity for PS orbit III.

V. COMPARISON WITH OCCULTATION AND VISUAL OBSERVATIONS

Evans (1984) has summarized the occultation observations, and PS concur with Evans in his altering of the events reported by the first two occultation observers. (See Table 1C of PS for the collected occultation results.) The six published occultation measurements place the secondary to the east of the primary at four epochs between 1978.72 and 1980.60. This alone does not contribute to the discrimination between the short- and long-period orbits, but it is entirely consistent with the quadrant behavior determined from the speckle observations.

Evans (1984) concluded from the collection of magnitude differences derived from occultation traces that the magnitude difference at 4472 Å is 0.39 mag. There is considerable scatter among the individual determinations of the magnitude differences in the blue, but there is no indication of any inconsistency between the photometric results from the speckle and occultation data.

The residuals of the occultation observations gathered in Table 1C of PS to the 6 yr orbit of PS and to our new orbit have average values of $+0.0002 \pm 0.0042$ arcsec for the PS orbit III and -0.0018 ± 0.0049 arcsec for our orbit. The residuals to the two earliest occultation observations are comparable between our orbit and PS orbit III, but the four later events, three of which were collected by Peterson and his collaborators, are better represented by the PS orbit. We consider the occultation measurements to be well represented by our new orbital solution, and particularly so in light of the fact that they were not included in the data sample from which the solution was calculated.

We have also calculated the residuals for the two 6 yr orbits that are derived from the visual interferometer and micrometer measures tabulated in Table 1A of PS. The average residuals here are $\langle\Delta\theta\rangle = -11.8° \pm 19.2°$ and $\langle\Delta\rho\rangle = +0.034 \pm 0.019$ arcsec to PS orbit III and $\langle\Delta\theta\rangle = -5.0° \pm 15.4°$ and $\langle\Delta\rho\rangle = +0.027 \pm 0.015$ arcsec to our new orbit. Thus, the average residuals *and* their dispersions are smaller for our new orbit than for PS orbit III, even though the visual observations were completely ignored in our solution, with PS incorporating the visual position angles in theirs.

We thus conclude that the newly determined orbit for Fin 342 fits all the observational material, except for four of the six occultation observations, better than any previously determined orbit for the system. Complete coverage of periastron passage using speckle interferometry at a 4 m telescope will be impossible because the predicted angular separation is below the diffraction limit for some 150° of position angle. The speckle observations have eliminated any questions as to the true period of Fin 342 and have produced an orbit that can be considered definitive, within the limits of accessible periastron coverage, under the criteria defined by Worley and Heintz (1983).

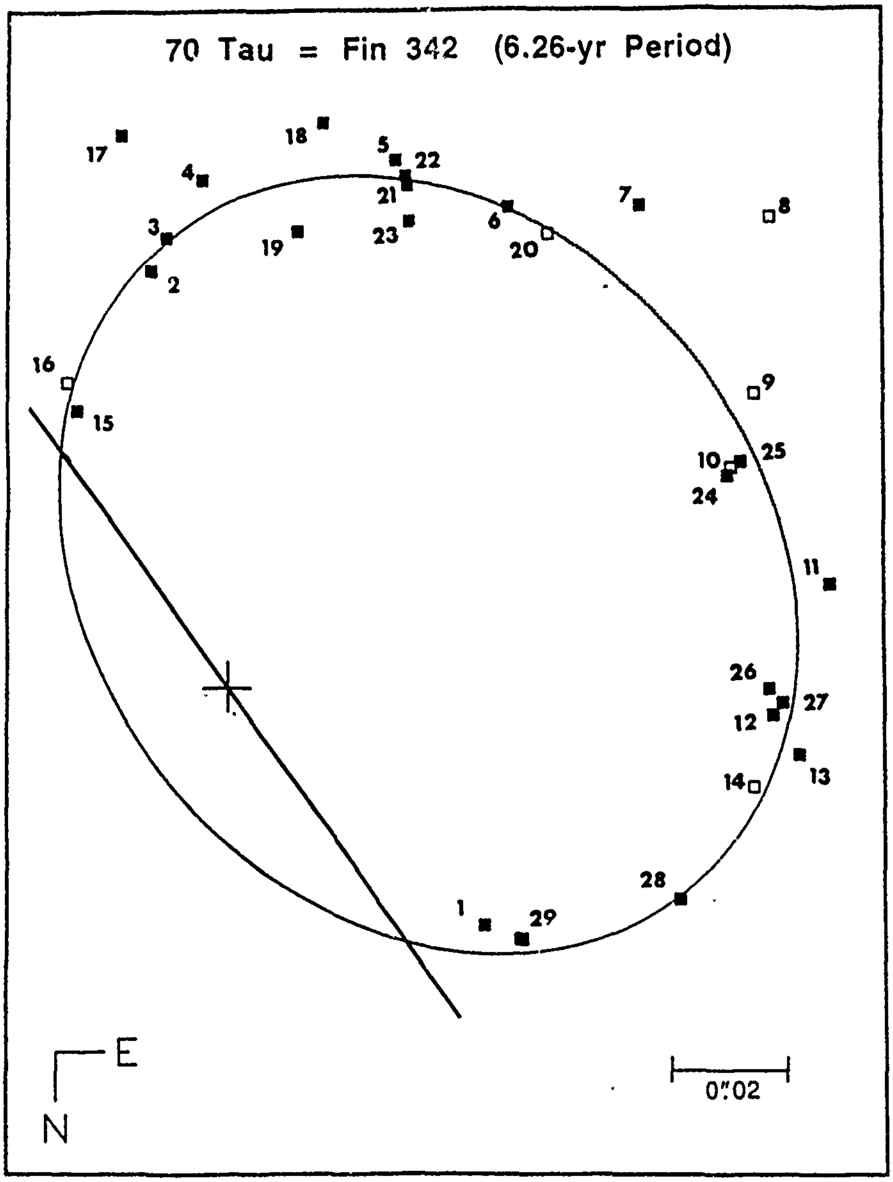

FIG. 2. The newly determined 6.264 yr orbit is shown against the interferometric measurements following the required quadrant reversals. The data symbolism is the same as in Fig. 1.

TABLE VI. Orbital ephemeris for Fin 342.

epoch	θ	ρ	epoch	θ	ρ
1988.50	23.6	0.040	1992.25	110.9	0.100
88.60	2.3	0.027	92.50	105.1	0.100
88.692[a]	315.4	0.018	92.75	99.1	0.100
88.70	310.6	0.018	93.00	93.1	0.099
88.80	245.8	0.028	93.25	87.1	0.098
88.90	225.7	0.041	93.50	80.8	0.095
88.979[b]	216.5	0.049	93.75	74.0	0.092
89.00	214.5	0.051	94.00	66.6	0.086
89.25	197.6	0.067	94.25	57.8	0.078
89.50	186.4	0.077	94.40	51.5	0.070
89.75	177.2	0.083	94.50	46.4	0.065
90.00	169.2	0.087	94.60	39.9	0.057
90.25	161.7	0.090	94.646[b]	36.5	0.053
90.50	154.7	0.093	94.70	31.5	0.048
90.75	147.9	0.094	94.80	17.9	0.036
91.00	141.5	0.096	94.90	348.3	0.023
91.25	135.2	0.097	94.956[a]	315.4	0.018
91.50	128.9	0.098	95.00	272.1	0.021
91.75	122.8	0.099	95.10	236.9	0.033
92.00	116.9	0.099	95.25	215.6	0.050

[a] Epoch of periastron passage.
[b] Epoch of nodal passage (maximum velocity separation).

VI. DISCUSSISON

The 3.6% increase in the total mass of Fin 342 that we find in comparison with the recent mass determination by PS results in an increase in log (mass) by 0.014. This will have some effect on the cluster distance determination carried out by McClure (1982) and modified by PS. We believe it premature to perform another revision of this calculation until we complete work in progress on the refinement of the orbits of several other Hyades binaries, including the resolved single-lined spectroscopic binary 51 Tauri.

It is possible to check for consistency between the new orbit and what might be expected for the masses of the components of Fin 342 according to the best present estimate of the cluster distance. Following McClure (1982), we use the proper-motion results that indicate that Fin 342 is only 2% beyond the mean cluster distance, although it might be noted that proper-motion determinations may suffer a bias when an unresolved photocentric motion is superimposed upon the space motion of a star. Small magnitude differences, such

as that of Fin 342, tend to make such a bias rather small, however. If we assume the cluster distance modulus given by PS of 3.36 mag, then Fin 342 has a distance of approximately 47.9 pc. Furthermore, using our newly determined magnitude difference of 0.34 mag at 5500 Å and the composite apparent magnitude of $V = +6.46$, we find for the individual components of Fin 342 the following photometric parameters:

$$m_a = +7.06,\ M_a = +3.66;$$

$$m_b = +7.40,\ M_b = +4.00.$$

These correspond to spectral types for the two components of F6–7 and F8, for which one expects approximate masses of 1.24 and 1.17 $\mathscr{M}_\odot$, respectively, for a total mass of 2.4 $\mathscr{M}_\odot$ (Allen 1973). The star 70 Tauri is most often classified as having spectral type F7. At a distance of 47.9 pc, the new orbital elements imply a semimajor axis of 4.7 AU and a total mass of 2.6 $\mathscr{M}_\odot$, a value in reasonable agreement with the photometrically expected masses. This system can now be considered a well-behaved member of the central region of the Hyades cluster.

Preliminary results from orbit revisions to other Hyades binaries that are now being carried out by us are indicating the possibility of substantial changes in mass determinations for several systems. For example, our new analysis of the motion of ADS 3248 (vB 75) leads to a total mass that is 27% smaller than implied by the catalog orbit (see Worley and Heintz 1983), causing vB 75 to shift significantly closer to the mean cluster mass–luminosity relation. We are also endeavoring to determine accurate magnitude differences through "speckle photometry" of the set of Hyades binaries accessible to speckle interferometry. These results should shed further light on the seemingly endlessly unfolding questions of the distance to the Hyades cluster.

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BINARY STAR SPECKLE PHOTOMETRY. I. THE COLORS AND SPECTRAL TYPES OF THE CAPELLA STARS

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ABSTRACT

Sets of speckle-interferometry frames of Capella taken in the Strömgren *y*, *b*, and *v* filters have been analyzed by means of the "Fork" algorithm to produce the intensity ratios of the components. The results show that the magnitude differences in *y*, *b*, and *v* are $m_{Aa} - m_{Ab} = 0.09$, 0.23, and 0.55, respectively. Thus, contrary to accepted beliefs, the more luminous star in these wavebands is the hotter Capella Ab, which is the spectroscopic secondary and the less massive component. The photometric indices are consistent with spectral types of G0 III for the secondary and G8/K0 III for the primary.

I. INTRODUCTION

A major goal of the GSU/CHARA program of binary star speckle interferometry has been to develop methods for accurately determining the magnitudes and colors of the individual components of binary stars with angular separations down to the diffraction limit. This paper is the first of a series of such "speckle photometric" analyses. In the present application, speckle observations provide a new, direct means for measuring the temperatures and luminosities of the components of the well-known spectroscopic star Capella.

Capella (α Aur, HR 1708) was independently recognized to be a spectroscopic double by Campbell (1899) and by Newall (1899). Because both stars are close in spectral type, the identification of the spectra of the two components and the estimation of the magnitude differences have been difficult. A spectrophotometric analysis by Wright (1954) appeared to settle the issue: The spectroscopic primary (Capella Aa; smaller radial-velocity amplitude; larger mass) was approximately type G5 III, and the secondary G0 III, with a magnitude difference at 5500 Å of about 0.25. For the past 34 yr, most work on Capella has taken these values as the starting point, although possibly assigning types G6–G8 to the primary. Recently, however, Griffin and Griffin (1986) have questioned Wright's assignment of relative magnitudes based on their integrated radial-velocity profiles, in which the spectrum was correlated with a mask. The most recent spectroscopic orbit has been determined by Shen *et al.* (1985). Further astrophysically important quantities can be found in the RS CVn catalog by Strassmeier *et al.* (1988).

Capella naturally is an attractive target for speckle interferometry with apertures greater than 2.5 m; McAlister (1981) has published a high-precision orbit. Various published and unpublished luminosity estimates have put the intensity ratio in *V* at between 0.6 and 0.9. Even the nodal quadrant recently was in dispute (see Griffin and Griffin 1986; Bagnuolo and McAlister 1983). The latter paper and Bagnuolo (1982,1983) estimated that the intensity ratio was 0.82–0.89 in *V*.

Clearly, it would be desirable to obtain intensity ratios in several standard filter bandpasses. In this way, the question of the spectral types of the primary and secondary could be settled and the physical parameters of the system obtained via photometric indices.

Difficulties in nomenclature may arise since speckle photometry incorporates various techniques and descriptions from the fields of speckle, visual, and spectroscopic binary research along with that of photometric photometry. A case in point is the designation of the "primary" component. The primary star in visual binaries is the brighter star (usually in the *V* bandpass). For spectroscopic binaries, the primary is usually the star with the more prominent spectral lines, although there are a few single-lined binary cases where the primary is the brighter star, even though its lines are not measurable. Other parameters can be used to define the primary, such as the more massive or the hotter. Obviously, these definitions are all correlated.

We have chosen to adopt the convention of the visual binary research, because speckle interferometry is its logical extension. Therefore, in the future, "primary" will generally refer to the brighter star in *V*. An exception will be made for Capella (and similar binaries), where the spectroscopic usage has been established by custom. Therefore, throughout this paper the Capella components will be referred to as the Aa and Ab stars. (They have also been referred to as the "G" and "F" stars, respectively, in the older literature, but because our photometric indices give spectral types closer to "K" and "G" we will not use this designation.)

II. OBSERVATIONS AND DATA REDUCTION

Speckle-frame data were collected in the Strömgren *y*, *b*, and *v* filter bandpasses in 1984 and in subsequent *y* filter runs in 1985, 1986, and 1987 with the GSU/CHARA speckle camera at the 4 m KPNO telescope (see Table I). The scale for the 1985 data was 0.008794″/pixel, whereas the other frames were at 0.005181″/pixel. The observing procedure

TABLE I. Capella magnitude differences.

Date	Filter	Δm
1984.0604	y	0.08±0.02
	b	0.22±0.02
	v	0.54±0.03
1985.8542	y	0.15±0.02
1986.8892	y	0.09±0.02
1987.7655	y	0.10±0.02

has been described by McAlister *et al.* (1987). These frames were recorded on videotape for later analysis.

The frames were digitized at GSU by a PC-Vision Plus frame grabber (Imaging Technology, Inc.) on an IBM-XT compatible host. By means of FORTRAN and 8088 Assembler programs, a central 128×128 pixel region of the 256×240 frame was stored in the "real" memory. Every other pixel was sampled from the original 512×480 frame. Thus, sets of up to 24 frames over intervals of 2 s were obtained. An 8 megabyte board in an IBM-AT compatible now allows up to 512 frames to be stored.

The flatfield data for the 1987 data showed a Gaussian-shaped "bowl" sensitivity decrease at the center of the frame due to gain losses in the microchannel-plate intensifier from the tube's extensive use. This loss has amounted to as much as 50% of the sensitivity at the edge of the original field where relatively few photons have been detected. The Capella data were flatfielded, and the estimated uncertainty in the result was improved by 30% via the Fork histogram analysis (see the discussion below). However, the omission of the flatfielding process did not lead to a significant bias in the result. Although the 1984 data were not flatfielded, the bias and increase in uncertainty were probably small since the microchannel plate was new at that time. With the assumption of linear wear, the data for 1985 and 1986 were flatfielded by 50% and 75% of the value for 1987.

Four sets of frames, comprising 80 frames total, were obtained for each data entry in Table I, except the b and v data from 1984, for which one hundred frames were obtained. The frames were analyzed via the Fork algorithm, which is described in more detail elsewhere, e.g., Bagnuolo (1988,1983) and Bagnuolo and McAlister (1983), in which it was referred to as "SSAA."

In brief, the Fork algorithm arises from the intuitive procedure of an observer viewing a double star frame—one looks for isolated speckle pairs, true replicas of the double star. Suppose that I_1, I_2, I_3, and I_4 are observed intensities at Fork points (like tines of a table fork) separated by the double star separation. Because the atmosphere is nearly isoplanatic over Capella-like separations, the observed double star intensities are produced by a single star pattern (psf) with intensities of $i_0,...,i_4$ shifted by the double star separation, multiplied by the intensity ratio r, and added to itself. Thus

$$\begin{aligned} I_1 &= i_1 + ri_0, \\ I_2 &= i_2 + ri_1, \\ I_3 &= i_3 + ri_2, \\ I_4 &= i_4 + ri_3. \end{aligned} \tag{1}$$

Obviously, there are too many unknowns to solve for r, but suppose that by chance i_2 is an isolated "glint" (i.e., $i_2 \gg i_1$ and i_3). Then, I_2 and I_3 form a nearly isolated pair and $r \simeq I_3/I_2$. Figure 1 is the central 64×64 pixel region of a frame from the 1986 data. Note the indicated four intensities and the isolated speckle pair where $r \simeq I_3/I_2$. Other speckle pairs are also visible. Thus, the Fork algorithm selects nearly isolated pairs by requiring that Max $(I_2,I_3) > C_1$ Max (I_1,I_4), and $> C_2\bar{I}$, where "Max" means "the greater," C_1 and C_2 are chosen constants, and $\bar{I}$ is the average intensity of the speckle frame where the Fork algorithm was performed. The last condition applies when photon or detector noise is present. An estimate of the intensity ratio from each such "favorable occurrence" is $r \simeq (I_3 - B)/(I_2 - B)$,

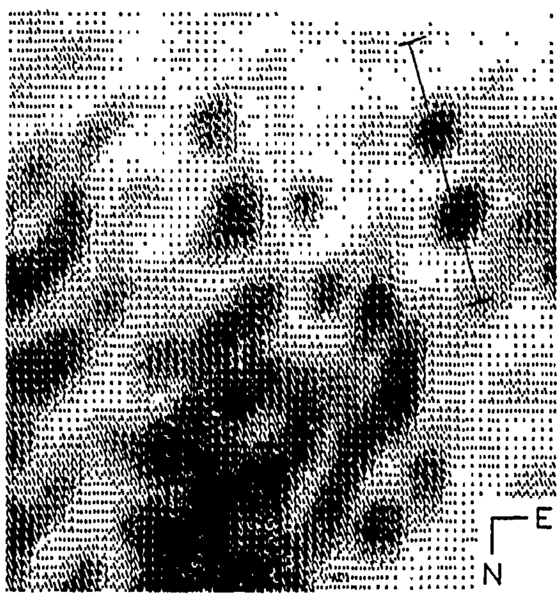

FIG. 1. A 64×64 pixel area of a speckle frame (1986, y filter) with a 22 level grey scale. A "favorable occurrence" for the Fork algorithm is indicated. The separation is 0".050, the intensity ratio is 0.91, and the position angle is 203°, as is indicated by this example.

where the background level is given by $B = (I_1 + I_4)/2$. These are referred to as "uncorrected estimates" below.

A better way is to estimate the two "contamination" terms in Eqs. (1) for I_2 and I_3, i.e., ri_1 and i_3. A straightforward calculation shows that

$$\begin{aligned} \overline{i_1} &= I_1R_1 - (1/Q), \\ \overline{i_4} &= I_4R_4 - (1/Q), \\ \overline{i_3} &= (I_4 - \overline{i_4})/r, \end{aligned} \tag{2}$$

where

$$Q = (1/r) - 1,$$

and

$$R_n = e^{I_nQ}/(e^{I_nQ} - 1).$$

The above estimates were obtained by assuming that the probability of intensity i is given approximately by an exponential distribution, and by integrating appropriate probability distributions. Therefore, the "corrected estimate" of the intensity ratio for this occurrence is

$$r \cong \frac{I_3 - \overline{i_3}}{I_2 - r\overline{i_1}} \equiv \frac{b}{a}.$$

The corrected estimates can also be appropriately weighted by their estimated uncertainties. The uncertainties in i_1 and i_3 lead to an uncertainty in the estimate for r and of a related quantity $f = r/(1+r)$, the fraction of intensity in the lesser component. It turns out that

$$\Delta f^2 = (b^2\Delta a^2 + a^2\Delta b^2)/(a+b)^4,$$

where

$$\Delta a^2 = r^2[I_1^2(1 - R_1)R_1 + (1/Q^2)] = \Delta i_1^2 r^2 \tag{3}$$

and

$$\Delta b^2 = (1/r^2)[I_4^2(1 - R_4)R_4 + (1/Q^2)] = \Delta i_4^2/r^2.$$

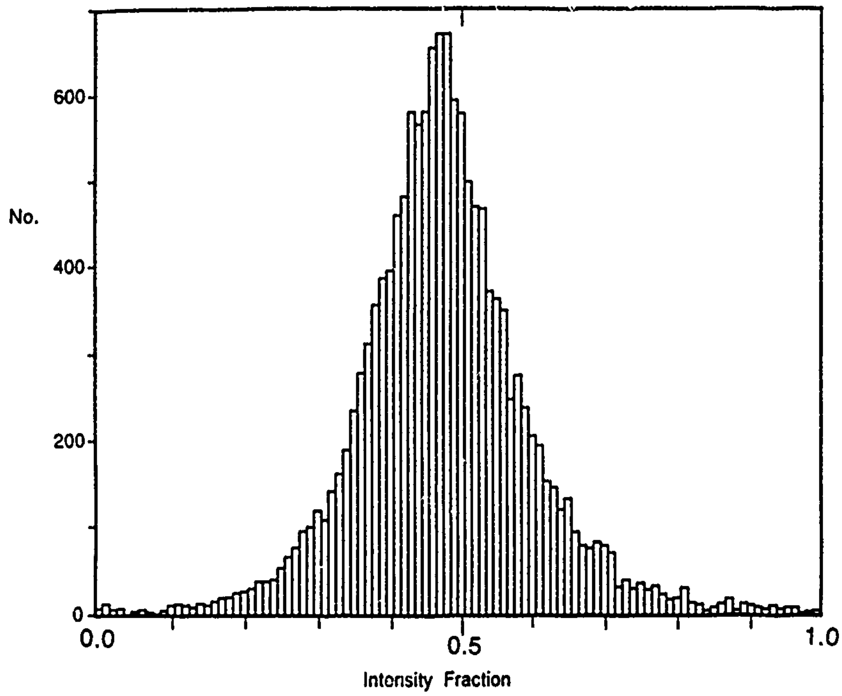

FIG. 2. Histogram for the 1987 y filter (corrected) data for 80 frames. The number of occurrences is plotted as a function of the intensity fraction.

One can compute an estimate of f for each occurrence, weight it by $1/\Delta f^2$, and store it in a histogram. Uncertainty estimates can also be modified for estimated modest photon or detector noise by incorporating an additional term in Eq. (3).

Figure 2 shows as an example a histogram of the corrected, unweighted estimates of y filter results from the 1987 data. According to the autocorrelation data and the orbit, the separation in pixels (x,y) was $(-1,9)$, which puts the fainter star almost due south of the brighter one. Parameters C_1 and C_2 were set at 2.25 and 1.3, respectively, for the Fork algorithm, and the average digitized intensity over the area in which the Fork code operated was about 45 in the y filter (in a 0–255 digitization range).

Table I lists the results for the Capella Δm values that have not yet been transformed to the standard Strömgren system. Somewhat surprisingly, the magnitude difference rises as one goes from y to v (5470 to 4100 Å). Therefore, the brighter component is the hotter Ab star (the spectroscopic secondary), and not the Aa star, contrary to the result of Wright (1954).

Note the basic agreement of the y measurements in Table I. The most discrepant point had data with the lower scale, which may account for the difference. The errors are obtained from the internal differences in the data and do not reflect possible systematic errors (e.g., detector nonlinearities).

On two other points of interest: First, the sense of the true position angle is determined by whether or not $I_2 > I_3$. On all four dates, the position-angle quadrants were determined to be in the same sense, that given previously by Bagnuolo and McAlister (1983). Second, we do not see any sign of photometric variability in this system.

The individual star colors now can be obtained from the integrated Capella colors, which were determined by Hauck and Mermilliod (1975) to be $b-y=0.513$ and $m_1=0.278$ mag. Taking the 1984 magnitude differences to minimize possible systematic biases, we thus find for the Ab star $b-y=0.451$, $v-b=0.655$, $m_1=0.204$; and for the Aa star $b-y=0.586$, $v-b=0.980$, and $m_1=0.394$. Figure 3 is a plot of the Capella components against standard G and K giants from Crawford and Barnes (1970). The best agreement is for G0 III and G8/K0 III components. Also plotted in the figure are sets of models from Kurucz (1988) and Bell and Gustafsson (1978).

III. DISCUSSION

It is evident that Capella Ab is almost 40% brighter compared to Capella Aa than was previously thought. Besides the work by Griffin and Griffin (1986), is there any other support for this in the literature?

At first sight, the integrated broadband colors might be different. Suppose we compare two models: Model I (standard model) with G6 III and G0 III stars having $\Delta m_v = 0.25$, and Model II (this paper) with G8/K0 III and G0 III stars having $\Delta m_v = -0.10$ (i.e., G0 star brighter). Synthetic broadband colors can be computed from the Johnson (1966) standards, incorporating some results from Bell and Gustafsson (1978). Table II (top) shows that the differences between these models are very small. The largest difference, in $U-B$, is only 0.04 mag.

Another approach is to look at the difference in the far UV and in the narrow IR bands. In the former, the earlier-type star (which dominates) will be 0.18 mag brighter in Model II than in Model I. In an analysis of *IUE* Capella data at critical orbital phases, Ayres, Schiffer, and Linsky (1983) stated that the "rapidly rotating F9 III secondary star in the system is considerably brighter than the more slowly rotating G6 III primary in the ultraviolet emission lines characteristic of the chromosphere ($T\sim6000$ K) and higher temperature ($T<2\times10^5$ K) plasmas." They remarked about "the extraordinary brightness of the Capella secondary in the far ultraviolet." This ultraviolet excess is perhaps less

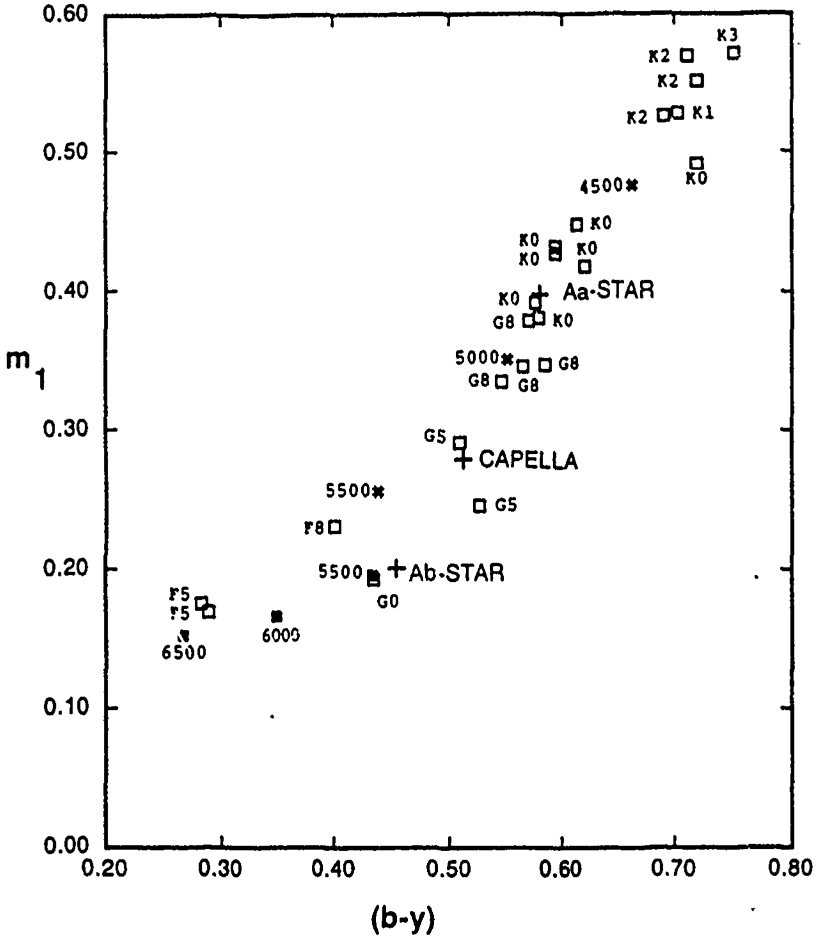

FIG. 3. Integrated Capella colors and individual colors of the Aa and Ab components are compared to stars (light squares) and to two sets of theoretical models (pound sign—Bell and Gustafsson; dark squares—Kurucz). The temperatures of the models are indicated.

remarkable if Capella Ab is 0.2 mag brighter in the visual than previously thought.

Some data in five IR photometric bands between 1.25 and 3.25 μm from NASA's *Lear Jet Infrared Observatory* were presented by Nordh, Olofsson, and Augason (1978). In this filter system, the bands "F1" to "F5" were centered at 1.2, 1.5, 1.75, 2.4, and 3.3 μm, respectively. The authors noted that by assuming the spectral classification and the light ratios given by Wright "after normalizing at filter F1 the model predicted too much flux at the positions of the filters F2, F3, and F5 (18%, 8%, and 14%, respectively), whereas the fluxes at the position of filter F4 were in agreement." They acknowledged that the data, especially in filters F2 and F3, were inconsistent with the spectral classification and magnitude differences given by Wright (1954). This discrepancy might be resolved by having the hotter, spectroscopic secondary be the brighter of the two components.

Finally, Koechlin *et al.* (1979) assigned a true nodal quadrant to Capella that appears to be 180° in error (see Bagnuolo and McAlister 1983). The CERGA group's method involved observing spectrally dispersed fringes between 5000 and 6500 Å; they assumed a magnitude difference of 0.25 in these wavebands. However, our observed intensity ratios and colors imply that the cooler Capella Aa is the brighter longward of about 6400 Å, which could explain their error (Vakili 1988).

To conclude, there does seem to be support in the literature that the hotter Capella Ab is the brighter star.

IV. SUMMARY

Assuming that the new spectral types are correct (G8/K0 III and G0 III), the intrinsic parameters for Capella (listed in Table III) have been obtained. Orbital parameters were taken from McAlister (1981). The stellar tempera-

TABLE II. Synthetic colors for two models.

Model	U-B	B-V	V-R	V-I	V-J	V-K	V-L	V-M	V-N
I	0.54	0.82	0.64	1.06	1.35	1.88	1.97	1.85	1.88
II	0.58	0.83	0.64	1.07	1.38	1.91	2.00	1.88	1.90

TABLE III. Derived quantities for the Capella components.

Spectral Type	Mv	log T_e	B.C.	log(L/L☉)	log(R/R☉)
G0 III	0.12	3.744	-0.04	1.844	0.958
		(3.763)	(-0.13)	(1.880)	(0.938)
G8/K0 III	0.23	3.681	-0.25	1.884	1.104
		(3.649)	(-0.40)	(1.944)	(1.198)

tures were based upor the models of Kurucz (1988) and Bell and Gustafsson (1978) for temperatures of 4800 and 5500 K, respectively. Values using the temperatures and bolometric corrections from Popper (1980) are given in parentheses in Table III.

Finally, it is interesting to note that our new spectral type for the brighter star is identical to that assumed by Eddington (1926). Sometimes the more things change, the more they stay the same.

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Seeing Stars with Speckle Interferometry

Harold A. McAlister

Astronomers view the universe through an atmospheric veil surrounding the earth that obscures a large part of the electromagnetic spectrum and distorts much of the remainder, including most visible and infrared wavelengths. Irregularities within atmospheric layers create small convection cells of air with slightly different temperatures and densities from the air in neighboring cells, and the differential refraction induced by this condition changes rapidly as winds blow the cells across lines of sight to celestial objects. This results in an image from a point source such as a star that is greatly blurred, changing in appearance on time scales of a few hundredths of a second.

For nearly a century, great observatories have been located on mountaintops selected after exhaustive searches for sites with the most transparent and stable air above them to minimize atmospheric effects on seeing. The latest effort at surveying sites was completed in April 1987 with the announcement by the National Optical Astronomy Observatories that the 16-m National New Technology Telescope would be located on the Hawaiian volcano Mauna Kea. Mauna Kea is well known for its excellent seeing conditions, with astronomers often reporting the blurring of stellar images—called "seeing disks"—to less than half a second of arc, compared to two to four times that amount at good sites in the continental United States.

New techniques enable astronomers to overcome atmospheric distortions of telescopic images, revealing, among other things, an unexpectedly large number of binary stars

To resolve detail finer than the seeing limit imposed by the atmosphere, astronomers have long dreamed of putting large telescopes in space or on the moon, where no gaseous medium can blur or filter out light from astronomical objects. The finest resolution of such telescopes would be the ultimate limit imposed by the diffraction of light, a limit inversely proportional to the diameter of a telescope's objective mirror. Thus a telescope such as the 5-m aperture (200-inch) Hale telescope on Mt. Palomar would be capable in space of resolving angular detail as small as 0.025 sec, equivalent to the angular size of a dime seen from a distance of some 80 km. The actual limiting resolution on Mt. Palomar is degraded by a factor of nearly 100, to somewhere around 2 sec. Thus this great telescope, capable of gathering one million times the light of a single human eye, can outperform the eye by a factor of only about 30 in angular resolution, doing no better than a department store telescope in this regard. The Hubble Space Telescope, with its 2.5-m diameter objective mirror, will yield images with unprecedented sharpness of detail when it is orbited by the space shuttle, surpassing even the best viewing from Mauna Kea by at least an order of magnitude.

As the scientific momentum behind the Space Telescope was building in the middle and late 1960s, a young French astronomer named Antoine Labeyrie was developing novel but not particularly difficult methods of observation and analysis to surpass the atmospheric seeing limit and, for certain types of objects, to reach the full diffraction-limited resolution expected from theory. Labeyrie gave this new approach the name "speckle interferometry" (Labeyrie 1970).

Speckle interferometry works by recording images using exposure times between 1/30 and 1/100 sec. During these brief instants, the distribution of turbulence can change by only a fraction of a typical convection cell's diameter, so that the pattern of blurring is effectively frozen. The aperture of a large telescope like the 4-m Mayall reflector on Kitt Peak will at any given instant contain hundreds of refractive cells, which create a random distribution of interference fringes in the image produced by the telescope; following Labeyrie's pioneering work, an individual fringe in the image is called a "speckle." Because each speckle contains contributions from locations distributed throughout the telescope's aperture, they all have characteristic sizes, which are directly proportional to the wavelength of light being observed and inversely proportional to the aperture of the telescope. For a 4-m telescope, speckle diameters turn out to be approximately 0.030 sec in visible light. Each speckle is actually a version of what the telescope would see if there were no atmosphere. Thus a speckle

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image is a kind of multiple exposure containing hundreds of complete representations of the astronomical object.

Cameras used to record speckle images at high magnification typically have fields of view of only two or three seconds compared to the many minutes of arc in normal astronomical photographs. Because of the very short exposure time required to freeze the pattern of atmospheric distortion, any single exposure will have to take advantage of as many of the incoming photons as it can. The light is amplified by an image intensifier tube and recorded by a highly sensitive electronic detector with very low noise.

The speckle camera we have developed at Georgia State University incorporates high magnification optics, a spectral filter assembly, and prisms that correct for atmospheric dispersion as objects are observed at varying distances from the zenith. The entire system is operated by computer. The camera produces 1,800 speckle images in one minute and can easily detect objects as faint as tenth magnitude, some 40 times fainter than can be detected by the unaided human eye. Longer integration times have been used to reach objects such as Pluto that are several hundred times fainter still. Figure 1 shows a speckle image of a single star alongside a 4-sec exposure from the same data set. It is apparent from these two examples that exposure times exceeding the rate of atmospheric change blur the information carried in the speckle exposures.

The analysis of speckle images involves measuring the average spatial information at the limiting scale-sizes of the speckles. In an early and conceptually simple analysis of an image of the cool supergiant star Betelgeuse, Lynds and his co-workers (1976) treated each speckle as a distorted and noisy approximation to a diffraction-limited image of the barely resolved star. By centering and stacking hundreds of individual speckles in a computer to improve the signal-to-noise ratio, they produced a "picture" of the surface of Betelgeuse, the first of the surface of any star other than the sun. Much of the structure in this intriguing image is smaller than the limiting resolution of the Kitt Peak 4-m telescope at which the data were obtained and must be attributed to residual noise following processing. Indeed, although Betelgeuse is resolved at the telescope's diffraction limit, its disk is only about three times the diameter of the smallest disk resolvable by the telescope. No more than a dozen supergiant stars in our galaxy are large enough and near enough to the sun to have angular diameters resolvable by speckle interferometry at the largest existing telescopes, and thus the applicability of the method to the measurement of stellar diameters is limited at present.

The ubiquitous binary stars

Binary stars are the special objects of speckle interferometry. A binary star is actually a pair of stars bound by their mutual gravity into elliptical orbits about their center of mass. The determination of the orbital elements of a binary star—dynamical and geometric parameters describing the relative motion of the two stars—provides the only means available for determining stellar masses (see Heintz 1978). These quantities are of fundamental importance to astrophysics and to our understanding of the complete evolutionary history of stars, and yet they are in short supply (Popper 1980). This is the last area in which the human eye still makes direct measurements at a telescope.

Evidence painstakingly accumulated during the last

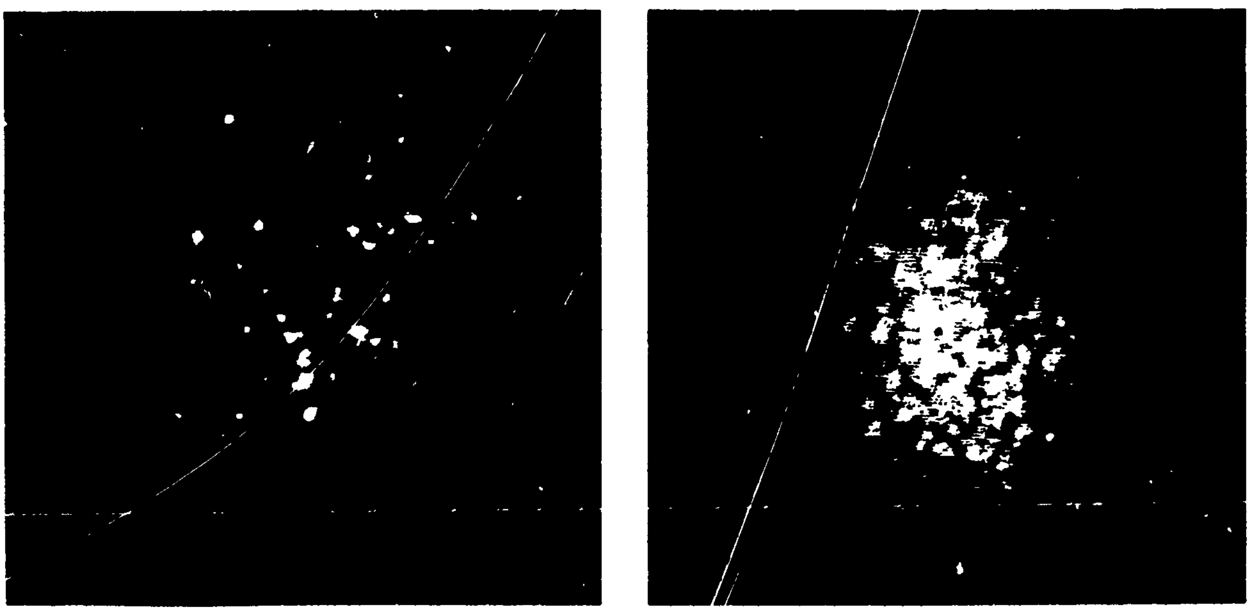


Figure 1. Speckle interferometry, a technology developed during the past 20 years, allows astronomers to overcome the distorting effects of the earth's atmosphere by photographing celestial objects at very short exposure times. A speckle image is a kind of multiple exposure, with each individual speckle containing a complete representation of the object. The speckle image of a star on the left was obtained at the 4-m telescope on Kitt Peak using an electronic camera with an exposure time of 1/30 second. The field of view is just under 3 sec of arc. In a four-second exposure of the same star (*right*), the fine speckle detail has been blurred by the rapidly changing atmosphere. (All photographs are by the author.)

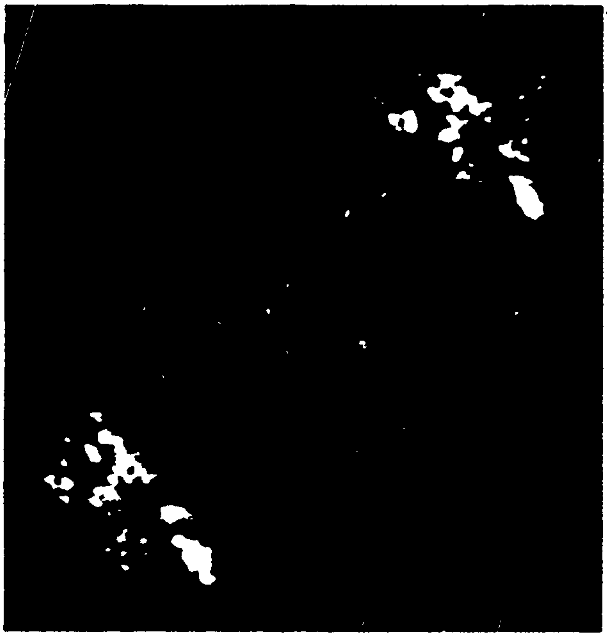


Figure 2. Speckle interferometry has proved particularly useful for observing binary stars, apparently the great majority of stars in our galaxy. It can resolve companion stars in binary systems at separations much too fine for the visual method to distinguish. As long as the stars are separated by no more than a few seconds of arc, their light undergoes the same atmospheric distortion and thus can be resolved in a single speckle image. This image of the binary star ADS 11483 with an angular separation of 1.6 sec was taken at the 3.6-m Canada-France-Hawaii telescope under the excellent seeing conditions that prevail on the volcano Mauna Kea.

half century indicates that most stars in our galaxy exist not as single objects but as companions bound in binary systems. This mutual association of stars carries on to triple and higher order systems, pointing to our need to understand why stars form in such groups rather than as single objects. The only star that is conclusively known not to be in a binary or multiple system is our own sun, and yet it is accompanied by the giant gaseous planet Jupiter, a kind of near miss at being a star in its own right. Labeyrie's method of speckle interferometry offered a revolutionary way of detecting new binaries and measuring thousands of known systems because of its greatly increased resolution and accuracy in comparison with the classical methods.

Speckle interferometry provides a means for resolving binary stars with angular separations down to the diffraction limit and for measuring their orbital motions with greatly improved accuracy in comparison with the visual method. Much of this increased accuracy depends on a property known as isoplanatism, which results from the equal distortion of the individual stars in a binary system as long as they are separated by no more than a few seconds. Figure 2 shows a speckle image of a binary star system with an angular separation of approximately 1.6 sec. The speckle patterns of the two component stars correlate highly, and the geometry of the system is repeatedly preserved in the individually correlated speckle pairs. The image was taken on Mauna Kea under superb seeing conditions, so the speckle patterns arising from each star are well separated.

An efficient method for measuring the average geometry of a binary system from a series of speckle images begins with what is known as a vector-autocorrelation, which measures all possible separations and orientations between all of the pairs of speckles in a single image. Imagine making a two-dimensional representation in which you place each speckle in turn at the origin and then plot the positions of all the speckles around it. If an image contains a total of N individual speckles, the vector-autocorrelation of the image is produced by N plottings. You continue adding to the representation over many hundreds or thousands of such images, and the geometry of correlated pairs shows up as two peaks on either side of a bright central peak at the origin, with the other random pairs contributing a smooth background extending over an area equivalent to that of the seeing disk. The geometry is then measured by eliminating the smooth background and determining the separation between the two outer peaks. The central peak arises from the superimposition of every speckle. This processing method can easily be carried out with specialized computer hardware as the data are taken at the telescope.

Figure 3 demonstrates the method for a binary star with an angular separation of a few tenths of a second. The seeing conditions under which the data were obtained are typical of Kitt Peak, with the result that the individual speckle patterns of the two stars cover each other. The vector-autocorrelogram on the right provides very strong peaks that can easily be measured with a precision better than 0.002 sec. A feature of this method of analysis is that the location of the fainter star with respect to the brighter star of the pair is ambiguous by 180° of position angle. This ambiguity is usually settled by visual observations of the system, as experienced observers can make micrometer measurements of binaries with such small angular separations. Visual measures, however, are less accurate than speckle results by at least an order of magnitude.

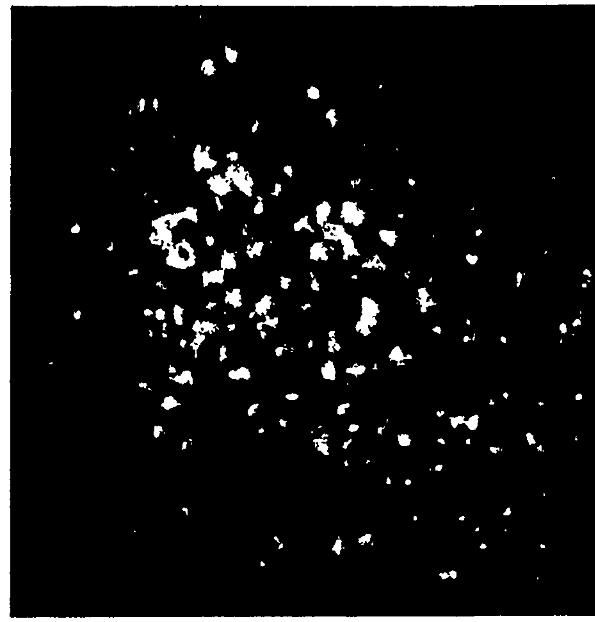
More sophisticated reduction techniques than vector-autocorrelation not only settle the ambiguity for the systems uniquely resolvable by speckle interferometry but also provide a determination of the brightness ratio between the two stars. This additional information is important for the complete astrophysical description of a binary star system. Labeyrie (1978) and I (1985) have both published reviews of methods and results from speckle interferometry as well as from other high-resolution techniques.

A terabyte of data

The speckle program of the Center for High Angular Resolution Astronomy has produced more than 85% of all high-resolution measurements of binary stars. Since 1975, our efforts have yielded some 6,300 measures of nearly 1,200 binary star systems during about 120 nights of observing at the Kitt Peak 4-m telescope, representing a terabyte of data. These results include the first resolution of 192 stars as binary systems. The average angular separation is about 0.38 sec, with nearly 20% of the sample falling between 0.10 sec and the limiting resolution of 0.030 sec.

Many of the newly resolved pairs have orbital

periods of a decade or less rather than the many decades that are typical for visual binaries. One particularly informative example is 51 Tauri (Fig. 4). This binary system is a member of the Hyades cluster, a collection of stars of fundamental importance in calibrating the cosmic distance scale. Hyades binaries provide one way of determining the distance to the cluster and also furnish unique information about the way that evolutionary effects in stars created at the same time with the same chemical abundances are dependent on the stars' masses. Just observed through one complete revolution, 51 Tauri promises to be one of the most important of the Hyades binaries in settling a number of issues that have been debated over the years.



Many other systems with relatively long periods have been observed during so-called periastron passages, when the two stars approach closest to each other and, as Kepler's second law dictates, their angular velocities are greatest (Fig. 5). Many such systems are unresolvable by classical methods around periastron. The new speckle measures provide critical information about their orbital elements and hence their masses.

The most important kind of binary system resolvable by speckle observations is that whose component stars have never been directly resolved but are revealed through their separate contributions to the system's spectrum. If their orbital motions are sufficiently rapid, the two sets of features will move oppositely through the spectrum in accordance with the Doppler effect, and the velocities of each of the stars along the line of sight can be measured. The direct resolution of these "double-lined spectroscopic binaries" permits the combination of angular measures of separation with linear measures of velocities to determine not only the masses of the component stars but also the systems' distances from the sun.

We have resolved a handful of such spectroscopic binaries, but the great majority of these systems have angular separations too small to be measured by current speckle methods. Successfully resolved examples include 12 Persei and Phi Cygni, the former consisting of two stars only

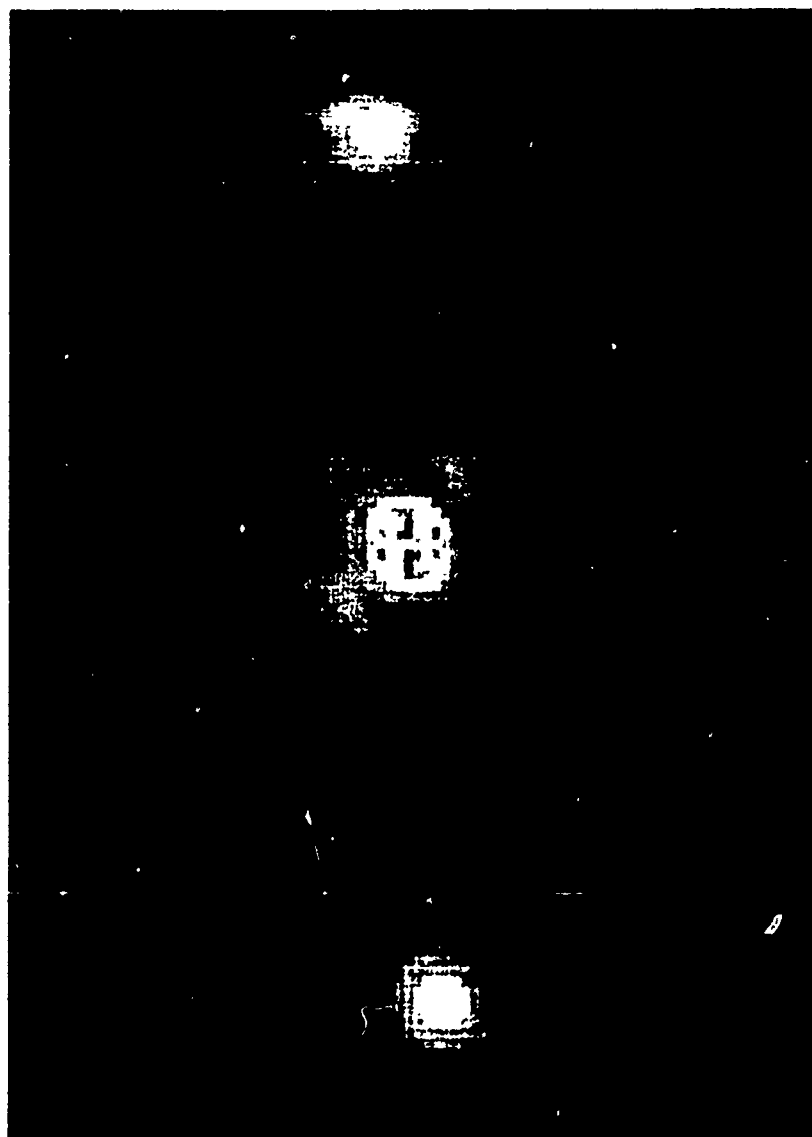


Figure 3. The binary star ADS 7158 has an angular separation of 0.24 sec, so close that the speckle patterns of the two component stars cover each other in an image taken with the Kitt Peak 4-m telescope (*top*). A vector-autocorrelogram (*bottom*) gives an accurate measure of the angular separation and relative orientation of the two stars. The two outer peaks in this computer-generated image represent the paired speckles in nearly 2,000 individual speckle frames like the one at the top. The bright central peak results from the superimposition of every speckle.

slightly hotter and more luminous than the sun, the latter comprising two stars that are similar in temperature to the sun but have evolved to giant stars. Although our results for 12 Persei agree well with stellar evolutionary theory, the luminosities for the stars in Phi Cygni are significantly greater than expected. We have also found this departure from theory in two other spectroscopic binaries containing giant stars.

There are many specific stars for which speckle interferometry has already provided new orbital elements, and there are many more visual binaries with fairly long periods of revolution for which it will soon improve calculations of orbits based until now entirely on visual measures. These refinements can have very large effects on measurements of masses, as total mass is proportional to the cube of the major axis of the ellipse. Thus a 15% change in the determination of the major axis causes a nearly 50% alteration in the calculated mass. A typically large reassessment of stellar mass is shown in Figure 6.

Searching for extrasolar planets

Triple star systems have been discovered during measuring of previously known visual binaries. Others have resulted from attempts to resolve spectroscopic binaries predicted to have angular separations at the diffraction limit of the 4-m telescope but having a companion with slower orbital motion than the previously known component. The star Eta Virginis is a binary with a spectroscopically determined orbital period of 70 days and, being relatively close to the sun, is a good candidate for resolution by speckle interferometry. Continued speckle coverage has indicated a period of just over 13 years due to a previously unknown third stellar companion. It is possible that the 70-day period may yet reveal itself as the gravity of the unseen star causes the resolved system to depart from simple elliptical motion.

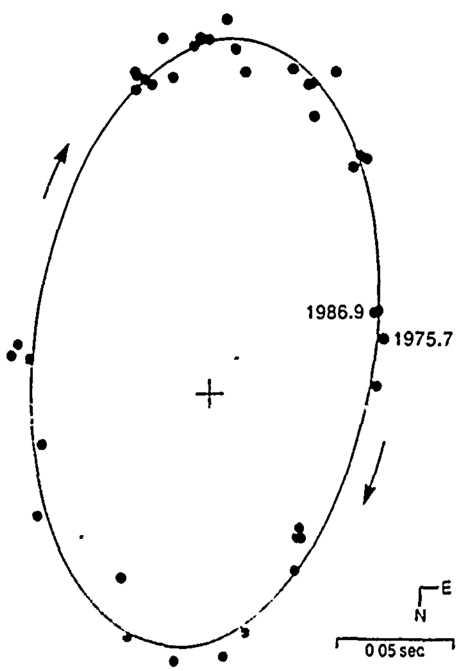


Figure 4. Many of the binary star systems that have been resolved by speckle interferometry have orbital periods much shorter than those previously observed by visual methods. Measurements of the motion of the fainter member of the binary system 51 Tauri around the brighter star (the latter represented as fixed in its location at the large + sign near the center of the ellipse) have refined estimates of the orbital period to 11.31 years. Colored dots represent speckle measurements; gray dots represent visual measurements. The new estimates will play an important role in calibrating the cosmic distance scale, because 51 Tauri is a member of the Hyades cluster, a collection of stars that provides a basic outward step in the hierarchical determination of distances in the universe.

This phenomenon is in fact the basis for one method of detecting planetary companions to stars. Since late 1982, we have been using the 72-in. Perkins telescope near Flagstaff, Arizona, to take monthly observations of a collection of 65 binary stars that are known to be within 85 light-years of the sun. By taking repeated measurements over a decade or so, we hope to decrease the observational errors so that departures from elliptical motions as small as 0.0002 sec can be detected. As is shown schematically in Figure 7, such small submotions could reveal the presence of planets with masses equivalent to Jupiter in orbit about one component star of a binary. Because planets are small and shine only by reflected light from their parent sun, they are hopelessly lost in their sun's glare and can be found only by indirect means.

Several search programs are in progress around the world, but ours is the only one involving binary stars. Other methods of detecting planets are in fact not applicable to binary systems. Calculations have shown that stable and even life-supporting orbits can exist in binary systems, and it is important that this dominant class of stars not be overlooked in the search for extrasolar planets. At present, there is no confirmed evidence for the existence of any planet outside our own solar system. It will be several more years before we can determine if our approach will achieve the required level of accuracy, but the scientifically and philosophically profound nature of this quest makes our efforts rewarding.

How many binaries are there?

We have already noted the seemingly limitless number of binary star systems. There are various ways to detect such systems, but a particular binary is rarely detectable as a binary by more than one. Speckle interferometry has pushed direct resolution into the realm of the spectroscopic binaries—that is, speckle observations can search for new systems that would have gone undetected in previous surveys.

Unfortunately, surveys of stars require large amounts of telescope time, a need that cannot be met in view of the stiff competition for very large telescopes. The urgency of the situation was stressed in late 1984 by Michael Shara of the Space Telescope Science Institute, who pointed out that the frequency with which the fine guidance sensors of the Hubble Space Telescope would encounter binary stars was probably underestimated because of the incomplete models of the galactic population distribution then available. The sensors cannot lock onto a binary star to provide a guiding and tracking

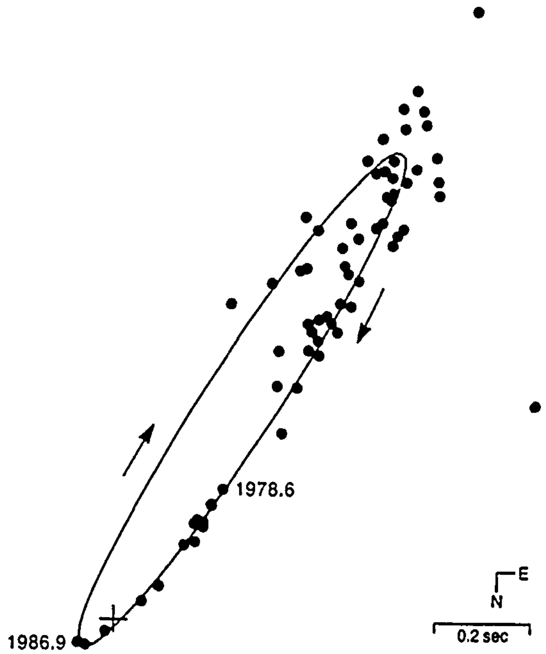


Figure 5. The star ADS 1105 was discovered to be a binary system in 1831; in that year its angular separation was 0.7 sec. When speckle data were first gathered in 1978, orbital motion was increasing rapidly because of the impending passage of the stars through their point of closest approach, or periastron, an event now known to have occurred in the fall of 1984. The two stars were separated by no more than 0.01 sec, too close to be resolved by visual methods. The orbital motion, which has now been determined for the first time, shows not only the rapid and critical periastron passage of the nearly 210-year orbit, but demonstrates as well the increased accuracy and resolution of the speckle measures (*colored dots*) compared to the visual measures (*gray dots*).

framework for observing another targeted object such as an extended galaxy. How often this might happen cannot be known in advance, so not only would this $1.4 billion instrument fail to observe a preprogrammed object, but it might spend the entire integration time collecting no useful data at all.

Shara urged a reassessment of the frequency of binary guide stars, then regarded as a kind of celestial vermin. Scientists from the Center for High Angular Resolution Astronomy were enlisted on relatively short notice to observe at several large telescopes, including the historic 100-in. Hooker telescope on Mt. Wilson, the 120-in. Shane telescope of the Lick Observatory, and the 3.8-m Canada-France-Hawaii telescope on Mauna Kea. After observing faint guide stars at the two continental telescopes, we decided to switch to observing bright stars. By selecting a sample containing the proper evolutionary blend, we hoped to arrive at an accurate figure that could be used by planners of the Space Telescope. In four nights on Mauna Kea under wonderful seeing conditions, we observed a sample of 672 bright stars, discovering 52 previously unknown binaries. This result more than tripled the estimated frequency of binary stars in the separation interval from 0.04 to 0.25 sec; Shara subsequently has predicted that nearly 20% of all guide stars will be unsuited to their task (Shara et al. 1987). The software for guiding the Space Telescope is now being modified to minimize the impact of this situation.

Whereas the Space Telescope's planners regard the increased estimate of duplicity as a pestilence, we find it scientifically intriguing. The survey of the more than 9,000 stars officially classified as "bright" is being continued, a few hundred stars at a time, during breaks in our regular program of measuring binary systems at Kitt Peak and follow-up runs on Mauna Kea.

We have also carried out a more limited survey among stars in the Milky Way showing very high velocities. Our results support an upward revision in the frequency of duplicity among older stars, which move differently from the population of younger stars like the sun. What was once thought to be a rare occurrence for the older generation of stars may actually be as common as it is among the more recently formed stellar population.

As a final group of objects in which new binary systems might be sought, we have surveyed not another collection of stars, but instead a sample of minor planets in our own solar system. Reports of such binary asteroids have appeared during the last decade, but in no case has incontrovertible evidence been put forth. We have completed the most extensive search to date by inspecting some 60 minor planets on two or more occasions each. We have found no evidence for the existence of double asteroids and must conclude that they do not exist within the limits of detectability by

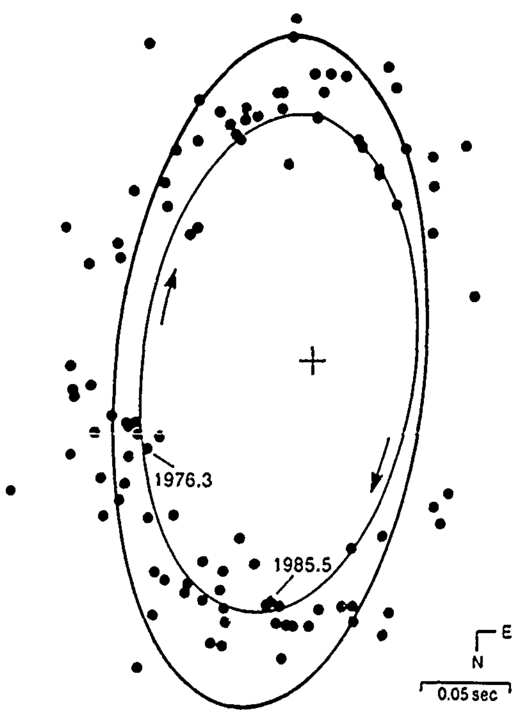


Figure 6. Speckle interferometry has provided revised estimates of the orbital elements of many binary systems. The speckle measures (*colored dots*) and visual measures (*gray dots*) of the system ADS 11520, whose period of orbit is 12.14 years, are shown along with the orbit previously considered definitive (*gray ellipse*) and the new orbit incorporating the speckle observations (*colored ellipse*). The total mass of the system is now known to be less than one-half that given by the previously accepted orbit, which was based solely on visual data.

speckle interferometry. Why our galaxy prefers binary stars but the solar system prefers single asteroids remains a mystery.

Future efforts

Speckle interferometry is far from exhausting its potential. Other groups active in the field, such as those at Harvard University and the University of Arizona, have emphasized the development of techniques for reconstructing high-resolution images from speckle pictures. This is a difficult task, but once perfected, speckle techniques will be widely used in astronomy, joining such standbys as photometry and spectroscopy. Imaging methods will be particularly important at infrared wavelengths, because many cooler objects associated with star formation radiate in the infrared and could easily be resolved at the diffraction limits of large telescopes.

Although speckle imaging will not be limited to objects such as binary stars that exhibit simple structures, the study of binary stars will benefit tremendously from certain types of imaging algorithms that not only reveal positional information but permit the determination of the individual brightnesses and colors of both component stars of a system. This means that in addition to determining the masses of the stars we can complete their astrophysical descriptions by extracting their luminosities and temperatures. No other method now exists for accurately determining this intensity-related information for binaries that are closer to each other than the seeing limit. We hope to be routinely performing "speckle photometry" along with our well-established speckle interferometry within a year or so.

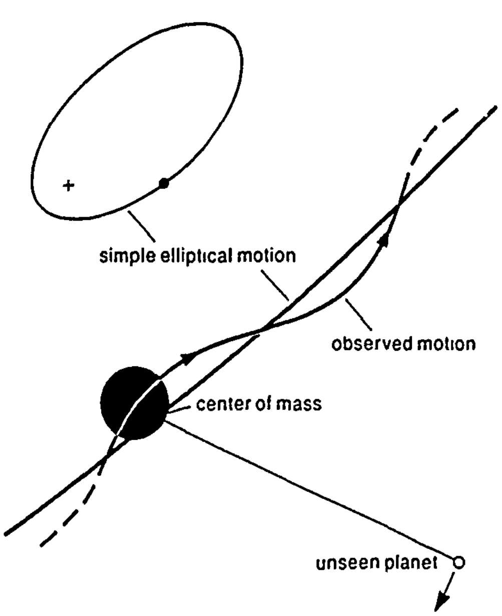


Figure 7. Unseen third companions of planetary mass in binary star systems can be detected if the orbital motion is measured with sufficient accuracy to reveal departures from simple elliptical motion. The complete elliptical orbit of a hypothetical binary system is shown at the upper left; the enlargement of a portion of the orbit shows the submotions of one of the stars, around which an unseen planet is presumed to orbit. The gravity of the unseen planet causes the submotions; at the same time, the center of mass of the system formed by the planet and the star follows the elliptical path. Evidence presented by speckle interferometry could help determine whether extrasolar planets exist.

But what about the push for ever higher resolution? The 10-m Keck telescope on Mauna Kea, which will be operated by Caltech and the University of California, is now well under way. Even larger national facilities are being planned, including the National New Technology Telescope in the United States and the Very Large Telescope, a European project to be located in the Southern Hemisphere. These behemoths will become the major observatories for the turn of the new century, designed to serve at the frontier of astronomical science. Although not specifically intended for high angular resolution astronomy, they will have some important applications to it.

The real breakthrough in the quest for higher resolution is taking place in the development of arrays of telescopes dedicated to interferometry, a technology perfected years ago at longer wavelengths by radio astronomers. Arrays can be made to achieve the resolution of a single enormous telescope if their focal planes are brought together to relay a commonly intercepted wave front of light to a beam-combining location. Achieving the necessary interference within the combined beams requires that the light paths in the arms be controlled to micron accuracies.

The application of this long-baseline interferometry at visible wavelengths began early in the century at the Mt. Wilson Observatory, but the valiant attempts made there during the 1920s and 1930s were generally frustrated by the lack of appropriate technology. The effort was abandoned for over thirty years until several groups began to develop multi-telescope interferometers in the early 1970s. Labeyrie built a two-telescope interferometer in France and began work on a separate system employing an array of 1-m telescopes of a novel spherical design (Labeyrie et al. 1986). Other projects around the world include an interferometer on Mt. Wilson (Shao et al., in press) and a linear array of 11 small telescopes on a 640-m north-south baseline now under construction in Australia (Davis and Tango 1985). The Australians have already measured the diameter of the nearby star Sirius using a prototype interferometer (Davis and Tango 1986). Several other projects aimed at infrared wavelengths are in various stages of development (Anderson 1987).

At the Center for High Angular Resolution Astronomy, we are planning a facility that will increase the available angular resolution by more than two orders of magnitude. Seven 1-m telescopes will be dispersed along three baselines radiating at 120° intervals from a central station. The circle circumscribing this array will have a diameter of up to 400 m, depending on the site at which it is eventually located. The beams from the individual telescopes will be carried through light pipes to the central station, where they will be directed into combining optics and detectors.

Our configuration is modeled after the enormously successful Very Large Array of radio telescopes located in New Mexico, but because of the resolution leverage of the short visible wavelengths, our interferometer will have more than a hundred times greater resolution. This wavelength advantage, however, quickly turns against us by imposing formidable mechanical and optical toler-

ances. It will be a challenge to produce the kind of images of extended objects for which the Very Large Array has become justly renowned. At the outset, our project will be aimed primarily at measuring stellar properties through the resolution of very close binaries and the surfaces of individual stars, but it has the potential for imaging complex objects.

The new interferometer will have a limiting resolution of 0.0002 sec, compared to the 0.030 sec we are now achieving by speckle interferometry on Kitt Peak. The dime that is now resolvable as a disk from 80 km will be measurable from a distance of 12,000 km! We can now expect to resolve a typical binary star at a distance of 80 light-years from the sun if its period of revolution exceeds about 0.7 year; the instrument we hope to build will be able to resolve binaries at this distance with orbital periods as short as 3 hours. It is now a rare and celebrated occurrence when we successfully resolve a spectroscopic binary, but the new interferometer will resolve virtually all the more than 700 such objects now known; it will increase the present handful of resolvable stellar diameters by tens of thousands. A long-baseline optical interferometer will be a revolutionary leap forward in fundamental observational astrophysics, furnishing a new perspective on the universe. It will cost about the same as a single 4-m telescope—around $8 million—but will provide 150 times the resolution.

Where it was once considered necessary to go into space to overcome the limitations of atmospheric seeing, we can now make progress without leaving the ground. But space still beckons with enticing prospects, particularly the imaging of faint objects over very long baselines and at extremely high resolution. Both NASA and the European Space Agency are studying the technology for large space-based interferometers, and some feel that such an instrument would be the logical follow-up to the Hubble Space Telescope. In space, an interferometer could have a baseline of many hundreds of kilometers, providing an almost microscopic view of the macroscopic universe. Thus the current activity in ground-based interferometry can be seen as a step in the development of a space interferometer.

For nearly four centuries, telescopes of ever increasing light-collecting area have pushed back the frontiers of our knowledge by detecting increasingly fainter objects in the universe. The complementary ability of large telescopes to resolve fine detail has been exploited for less than two decades. This is truly the beginning of a new manner in which we view and understand cosmic phenomena.

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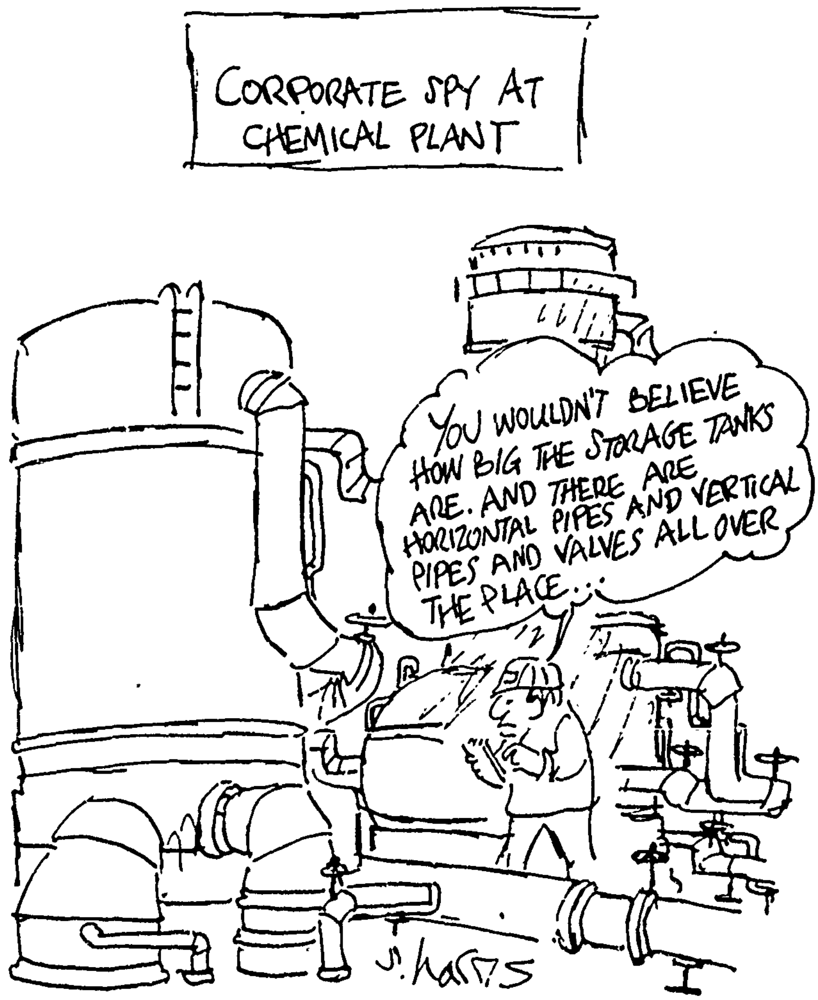

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BINARY STAR ORBITS FROM SPECKLE INTERFEROMETRY. II. COMBINED VISUAL/SPECKLE ORBITS OF 28 CLOSE SYSTEMS

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ABSTRACT

New orbital elements are presented for 28 close visual systems that have been observed and in some cases discovered by speckle interferometry. Periods for these systems range from 2.7 to 213 yr, semimajor axes from 0.″06 to 0.″81. Three of these systems (ADS 1105 = STF 115 AB, ADS 1473 = Ho 311, and ADS 14121 = Wck Aa) had no previously published orbital analyses, while elements for a number of other systems have undergone major revisions.

I. INTRODUCTION

The technique of speckle interferometry, as first suggested by Labeyrie (1970), has been in routine use by binary star observers for over 15 years now; in that time it has shown itself to be a reliable method for observing heretofore unresolvable systems (separations down to 0.″025 at the Kitt Peak 4 m) with unprecedented accuracy (down to ± 0.″001 for brighter stars with small magnitude differences). Over 7600 measurements of 1371 systems have been published to date by observers from institutions throughout the world. McAlister and Hartkopf (1988) have compiled a catalog of all binary star measurements made by modern interferometric methods and published to date; the median separation in the catalog is 0.″23, and 16% of the measurements are for systems closer than 0.″1.

Some 75% of these measurements fall within the separation range 0.″05–0.″5. At the typical distances of these stars, these translate to periods ranging from, perhaps, 1 to 100 yr, with the most common periods roughly 10 to 20 yr. Thus, speckle interferometry has now reached the point where many of its target systems have completed one or more revolutions and are ripe for orbital analysis. As will be seen, speckle observations may occasionally cover a crucial portion of a very long-period orbit, as well; two of the systems discussed in this paper have periods in excess of 200 yr.

Speckle-based orbit analyses accompanied by extensive discussion have been published for a number of interesting systems, including χ Draconis (McAlister 1980; Tomkin *et al.* 1987), γ Persei (McAlister 1982; Popper and McAlister 1987), Capella (McAlister 1981; Bagnuolo and Hartkopf 1989), the Hyades binary Finsen 342 (McAlister *et al.* 1988), β Per (Bonneau 1979), and several others. With this second paper in our series we begin more large-scale harvests of those orbits for which speckle interferometry has provided a significant contribution. The procedure used for deriving these orbits is described below, followed by a discussion of our weighting scheme, then new orbital elements and notes for 28 binary star systems.

Most of the systems in this paper were discovered to be binaries long before speckle interferometry was developed (for example, ADS 9757 = STF 1967 was first resolved by F.G.W. Struve in 1826). These visual measurements, although of lower accuracy than the speckle data, often provide a baseline of several orbital revolutions that may be used to tie down the period with considerable accuracy. In several of the calculations discussed below we have used all available data to determine the orbital period, then used only the speckle data and this period to derive the remaining elements. These "nonstandard" treatments of the visual data will be detailed in the individual star notes.

II. METHOD OF ORBIT CALCULATION

Programs for calculating orbital elements abound (see, for example, Eichhorn 1985; Heintz 1978a; McAlister 1981; Monet 1979, etc.), each with its own sensitivities. The program developed at CHARA is flexible and relatively straightforward in its mathematical formulation.

It can easily be shown that if the three elements P, T, and e are known, the four Thiele–Innes elements (A,F,B, and G—see Heintz 1978a for a definition of terms) and therefore the geometric elements a'', i, Ω, and ω can be determined by the method of least squares, as follows:

Given (P,T,e) and a set of observations (t_i,x_i,y_i), the eccentric anomalies E_i are found via the equation

$$u(t_i - T) = E_i - e\sin(E_i)\,, \qquad (1)$$

where

$$u = 360/P. \qquad (2)$$

Normalized rectangular coordinates X_i and Y_i are determined by the equations

$$X_i = \cos(E_i) - e\,, \qquad (3)$$

$$Y_i = \sqrt{1-e^2}\,\sin(E_i)\,. \qquad (4)$$

The four Thiele–Innes elements are then found by a least-squares solution of the equations

$$x_i = AX_i + FY_i\,, \qquad (5)$$

$$y_i = BX_i + GY_i\,. \qquad (6)$$

We perform a "three dimensional" grid search in the vicinity of a set of input values of P, T, and e, in each grid step calculating the remaining elements and determining an overall residual. Initial step sizes for the grid are adjustable; step sizes of zero may be used for any of the three elements (when, for example, the period is determined by other methods). After interpolating to arrive at a (P,T,e) set yielding minimum residuals, the grid spacing is reduced and the pro-

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cess repeated. The search ends when grid step sizes decrease below 0.01 yr in P and T, 0.001 in e.

In the next step, rms residuals are determined separately for visual and CHARA speckle data. Visual observations whose residuals exceed 3 times the visual rms are given zero weight, as are any speckle observations exceeding 3 times the CHARA speckle rms. The grid search is now repeated, this time running until step sizes fall below 0.0001 yr in P and T, 0.000 01 in e.

Formal errors for all the elements are determined from the covariance matrix of the final iteration.

III. THE WEIGHTING GAME

An essential aspect in the determination of binary star orbits is the decision on proper weights to be assigned each observation entering into those calculations. These observations may span 100 yr or more and may have originated from dozens of observers of varied experience and competence, using many different telescopes of different aperture and quality, and subject to a host of other uncertainties. These factors make the entire weighting procedure subject to the inevitable personal prejudices of the orbit computer. Our effort is no exception. We have endeavored, however, to keep our procedure as objective as possible by grouping observations into a minimum number of categories.

Four basic categories were defined as follows:

(1) First, as Fig. 1 will attest, observations made by modern interferometric techniques display a considerably greater internal accuracy than do the body of visual data. An obvious division of the data, then, is "visual" versus "speckle."

(2) The GSU/CHARA speckle observations, made with few exceptions on a single telescope by the same observers and using the same calibration method (see McAlister *et al.* 1987) are more internally consistent than other interferometric data. We therefore further subdivide these data into "CHARA speckle" and "other speckle."

(3) One would expect that visual observations made with larger telescopes should be more accurate than those made using smaller instruments. Charles Worley (1987) has noted roughly a factor of 2 difference in variance between visual observations made with telescopes of greater than versus less than 18 in. aperture. This observation is borne out by our calculations, as will be shown. We therefore divide visual observations into "small visual" and "large visual" bins.

In order to determine the relative weights to be assigned each of these four categories of observations, we calculated orbits for several well-observed systems and determined rms residuals for data in each group. There is of course a bit of circular reasoning inevitable in this approach, since weights must be assigned to the observations before calculating the orbits from which residuals, and eventually weights, are to be determined. We have tried to minimize this circularity by calculating orbits for various subsets of the data, as explained below.

The eight ADS binaries chosen for this exercise range in mean separation from 0\".15 to 0\".74, or approximately the middle range for all interferometric observations (McAlister and Hartkopf 1988). They are all extremely well observed, with a total of 2181 visual and 269 interferometric observations for the group and visual observations going back 162 years.

As a first step, separate orbits were calculated using the visual and the speckle data for each of the eight binaries. The "large" and "small" visual data were given initial weights of 1 and 0.5, respectively, for the visual orbit. For the speckle orbit, CHARA observations were given unit weight, except for the few Kitt Peak 2.1 m observations, which were given half weight. Other speckle data were given zero weight initially.

The results are given in Table I. The derived weights shown are calculated for each category from the formula

$$W_i = \left(\frac{\text{rms}_{\text{large visual}}}{\text{rms}_i}\right)^2, \tag{7}$$

i.e., 1/variance, scaled to a value of 1 for the "large visual" weight.

A new set of orbits was then determined from the combined visual and speckle data. Wishing to be a bit conservative in our speckle weights, we chose values of 0.5, 1, 20, and 5 for the four categories "small visual," "large visual," "CHARA speckle," and "other speckle," respectively. Half weight, or 10, was again used for the CHARA 2.1 m data.

The final results are similar to those earlier determined from the separate orbits. Again opting for a conservative weighting of the speckle data, we decided to adopt the earlier chosen values of 0.5, 1, 20, and 5 for initial weights in the four categories.

IV. RESULTS

New combined speckle/visual orbital elements are given in Table II for 28 binary systems. P, T, and their errors are given in years, a'' in seconds of arc, and i, Ω, and ω and their errors in degrees. All orbits are equinox 2000. Ephemeris tables (Table III) based on these orbits give predicted separations and position angles for the next 5–40 yr, depending on the derived period.

The figures below show the new orbits (solid lines) together with previously published orbits (dotted lines) and all published data (including data eventually given zero weight in the orbit calculations). Visual data from "small" telescopes are indicated by plus signs, those from "large" telescopes by hash marks. CHARA speckle data are shown as filled squares and other speckle data by open squares.

Notes to individual binary systems follow, sorted in order of WDS designation (the 2000-epoch right ascension- and declination-based designation used in the *Washington Visual Double Star Catalog* of Worley and Douglass 1984). A few of these systems have published orbits that are very similar to the ones listed here. Although it may be argued that these new orbits are therefore unnecessary, they are included as evidence that the method used by us for deriving orbital elements behaves properly and that the weighting scheme adopted is not unreasonable.

WDS 00352−0336=ADS 490=Ho 212 AB. Speckle coverage of this system now covers nearly two full periods. The period was determined based on all visual and speckle data, covering nearly 15 revolutions; speckle data alone were used to determine the remaining elements. The plotted published orbit is that of Gatewood *et al.* (1975).

WDS 01233+5808=ADS 1105=STF 115. This system, first resolved by John Herschel in 1831 at 0\".7, opened to 1\".1 in 1904, then closed steadily for 80 yr. By fortuitous timing it was first resolved by speckle in 1978 at 0\".35, just as visual measurement was becoming difficult. The separation de-

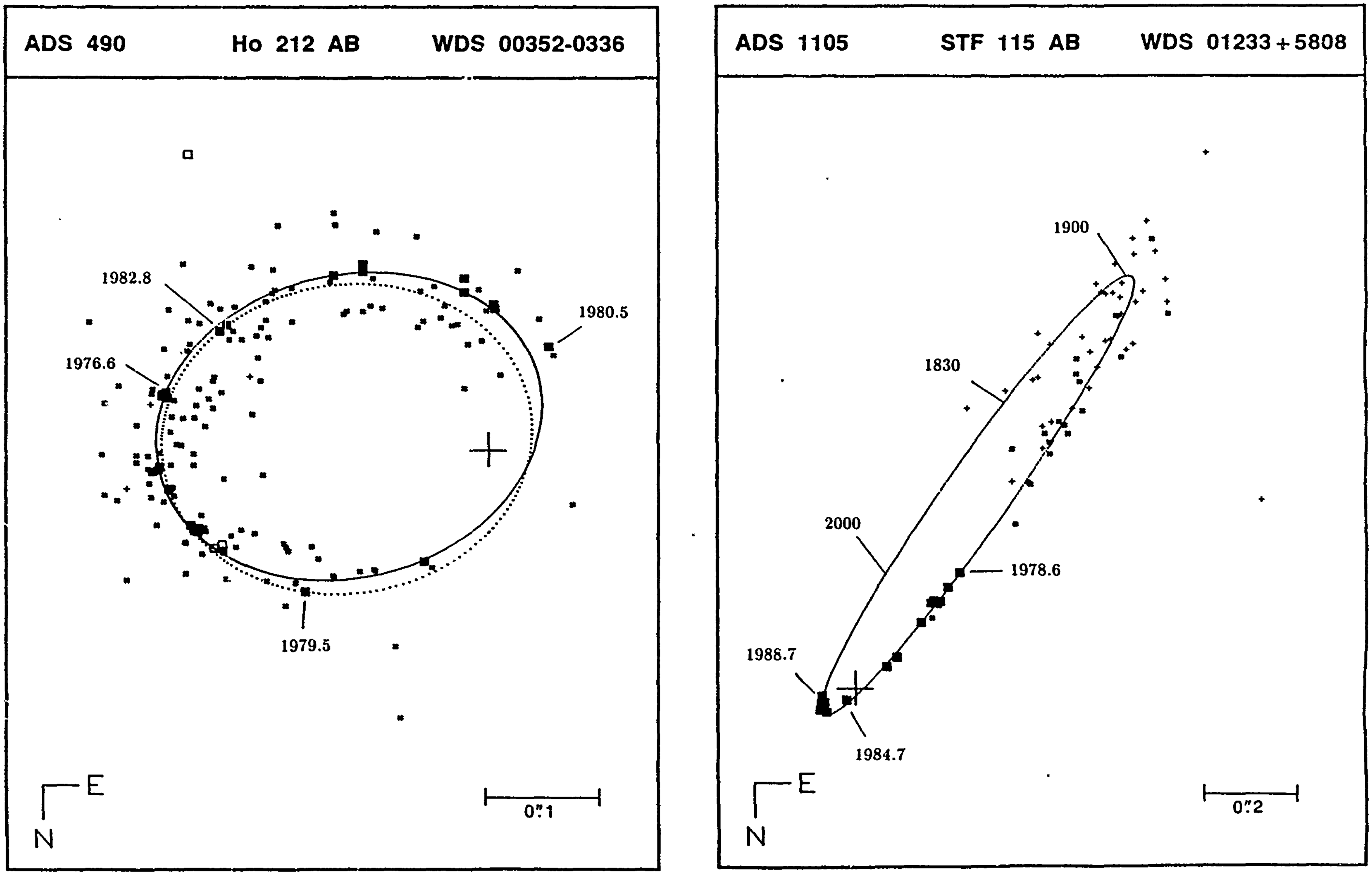
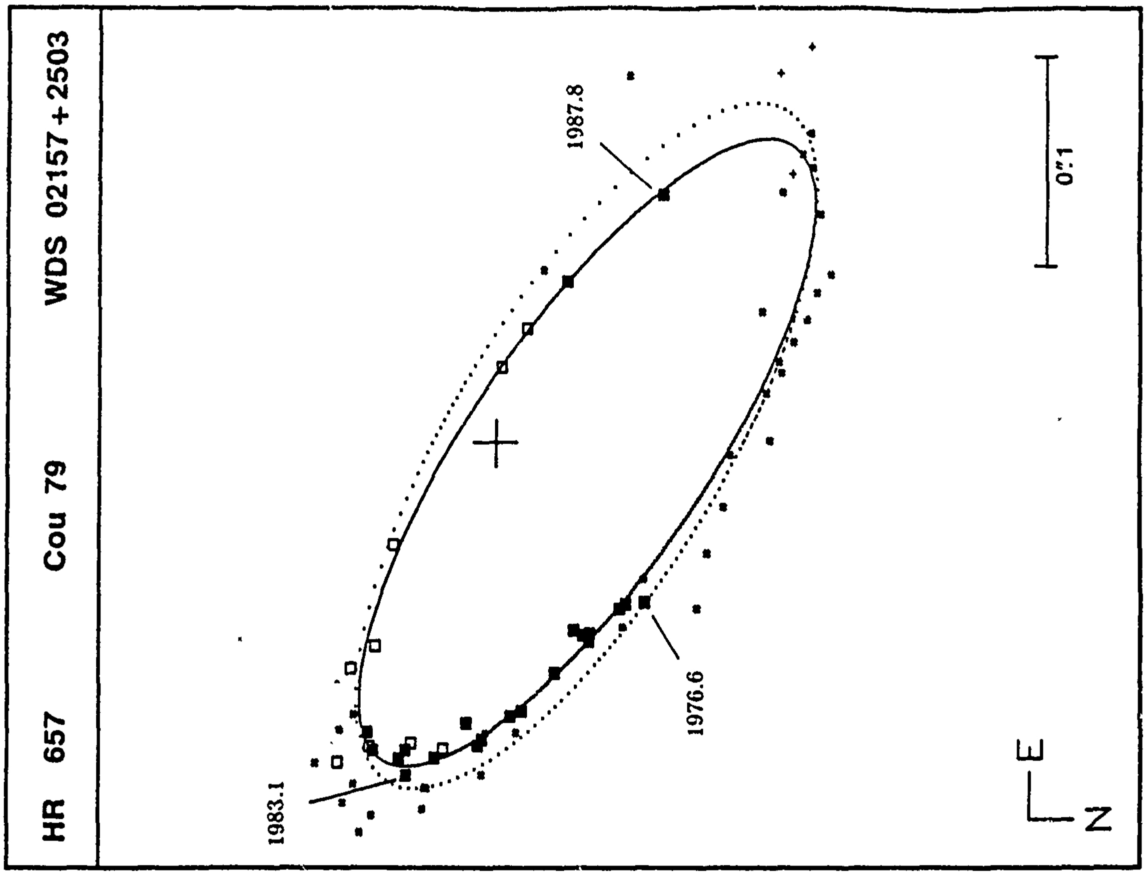
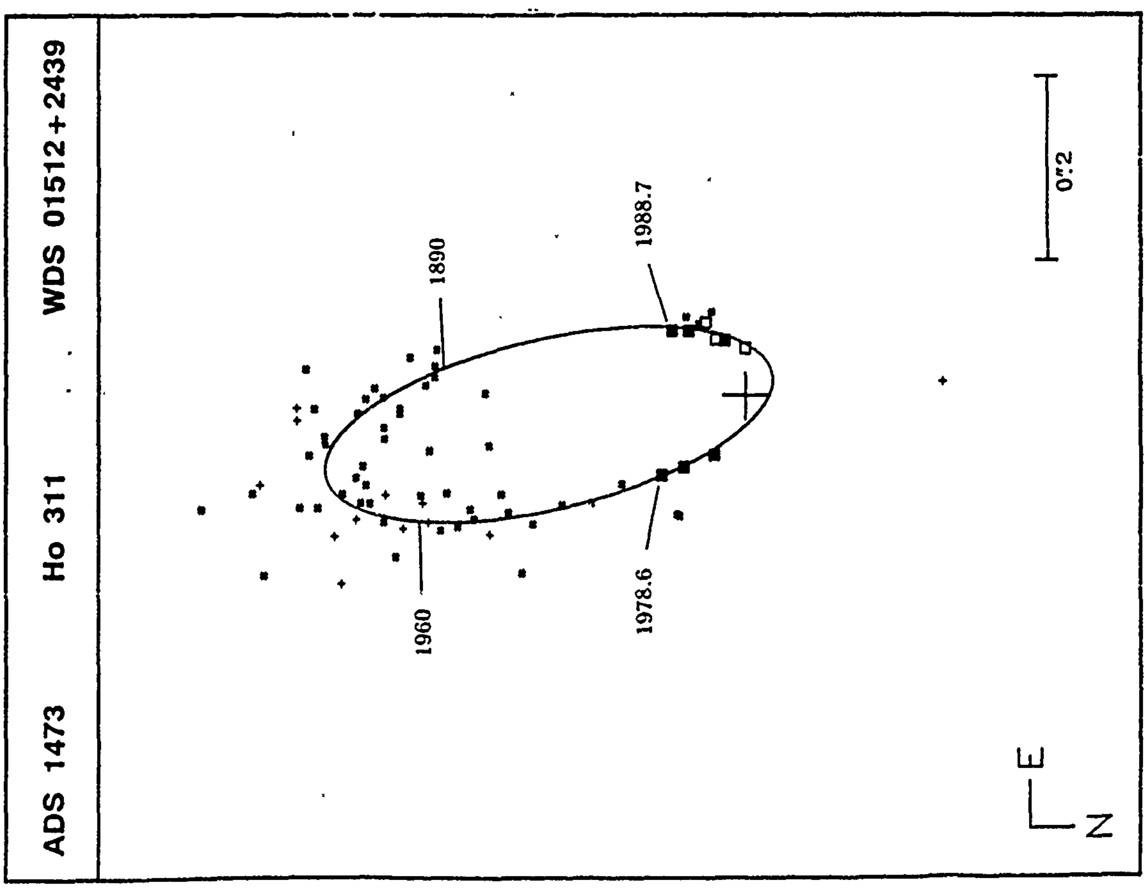


FIG. 1. Newly derived orbits for 28 binary star systems. In all plots which follow, "small" visual observations are indicatd by plus signs, "large" visual observations by hash marks, CHARA speckle observations by filled squares, and other speckle observations by open squares. Newly determined orbits are shown as solid curves, while previously published orbits (identified in the text) are shown as dotted curves. A few observations (dates given to the nearest 0.1 yr) and/or calculated positions (integer dates) are labeled on each orbit to indicate direction and rate of motion. Stars are plotted in order of WDS designation (or right ascension); note that the figures are not all plotted to the same scale.





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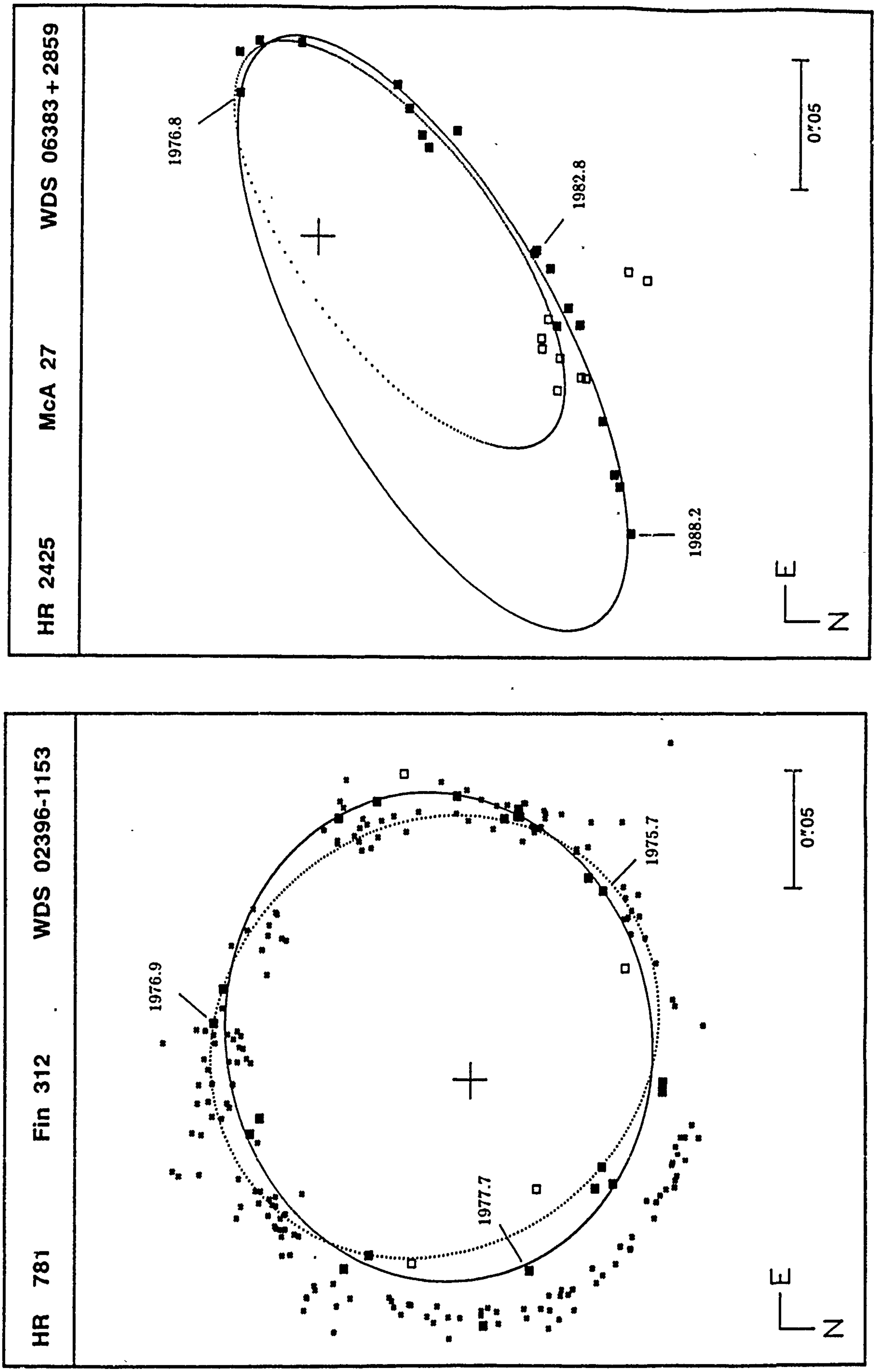

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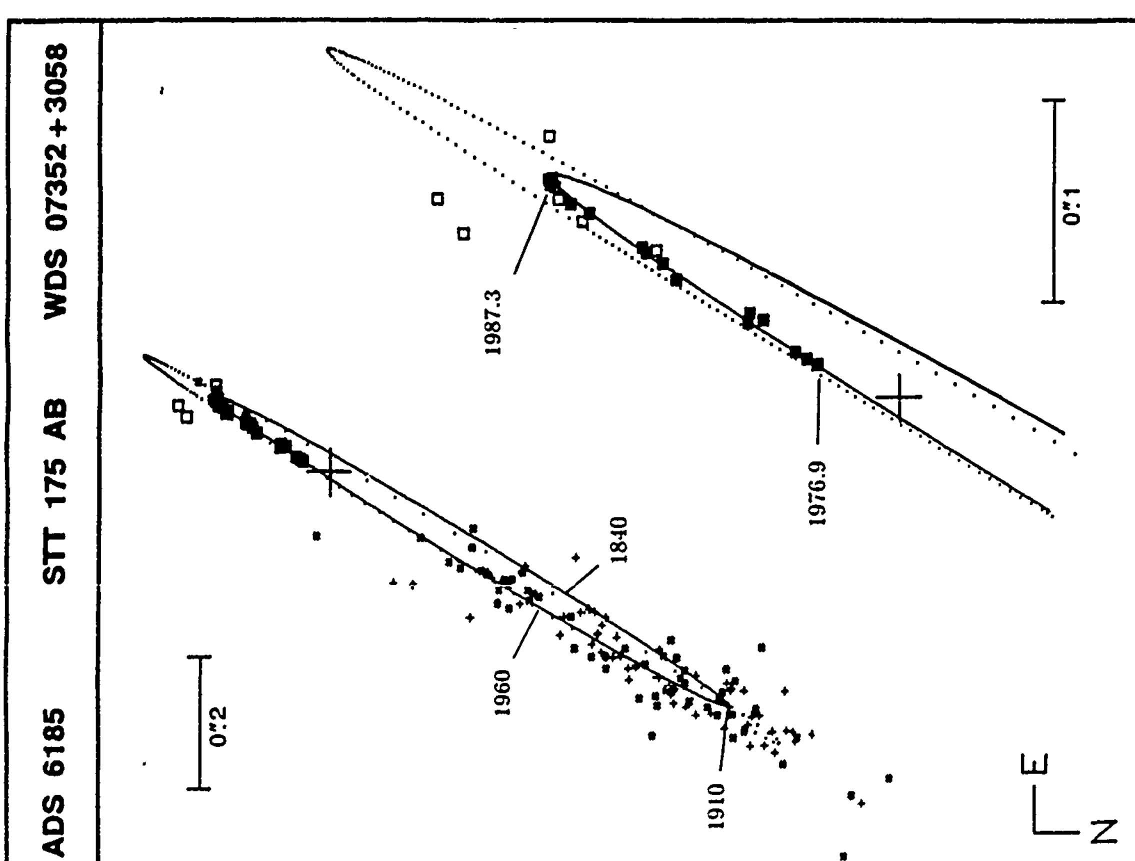

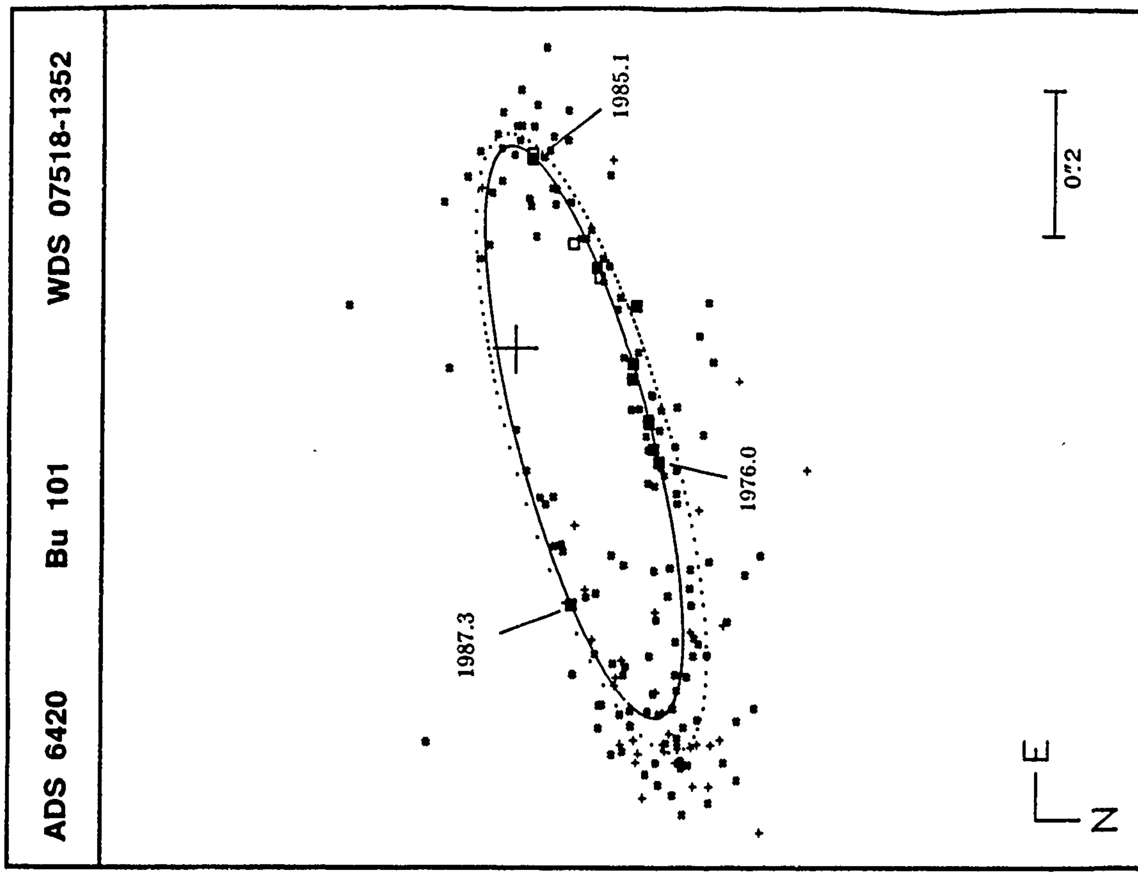

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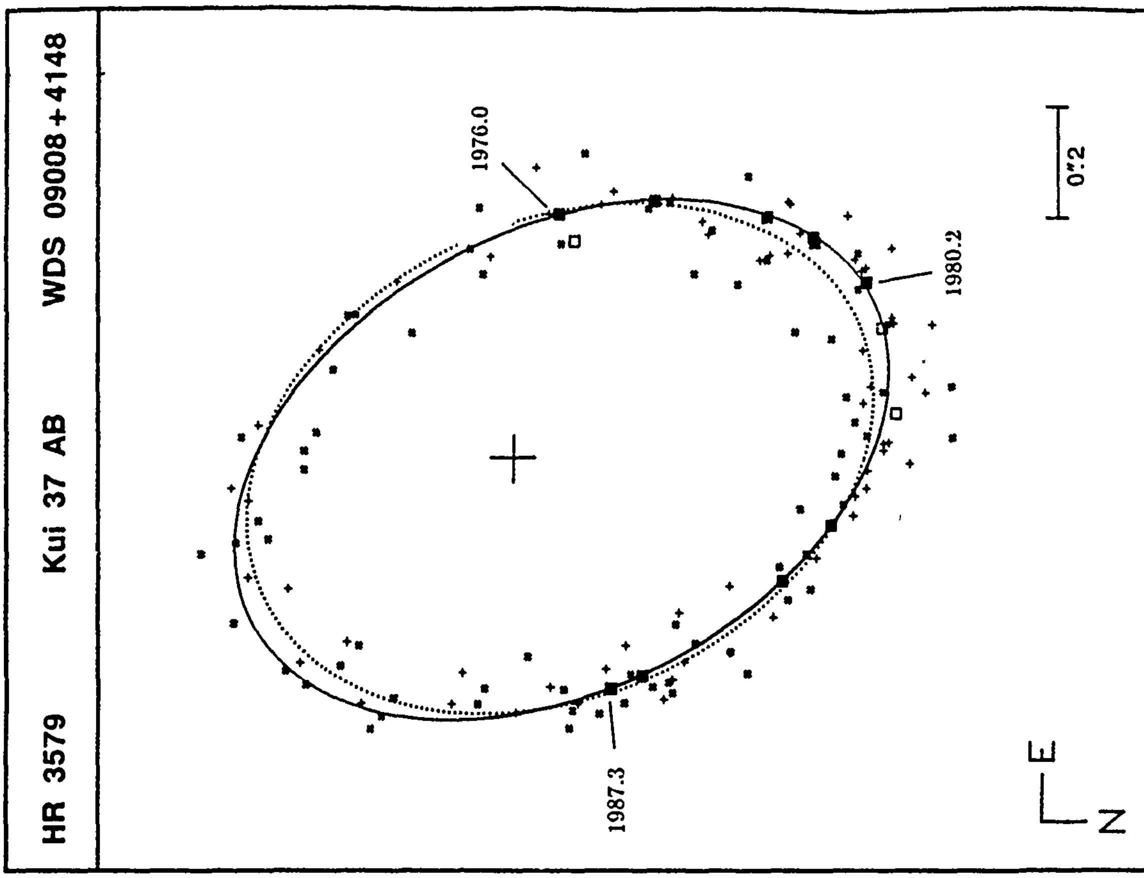

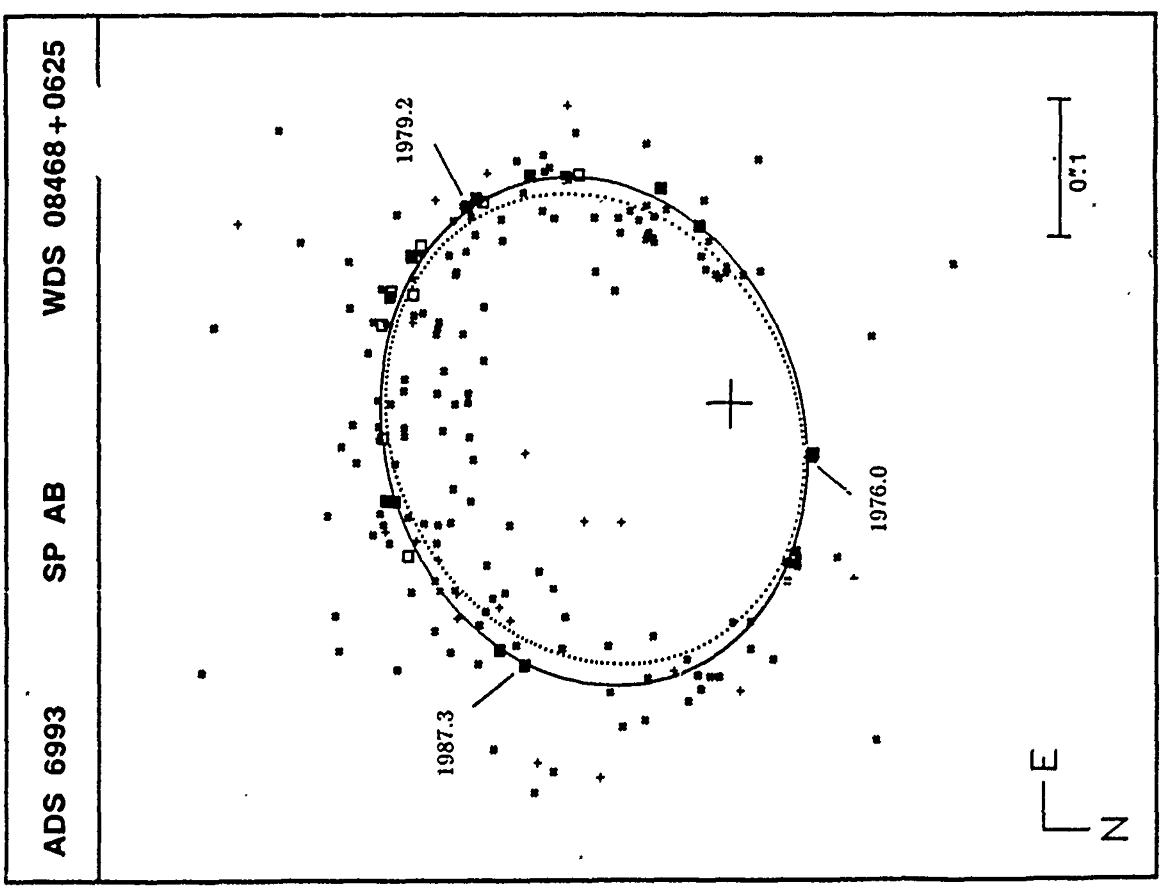

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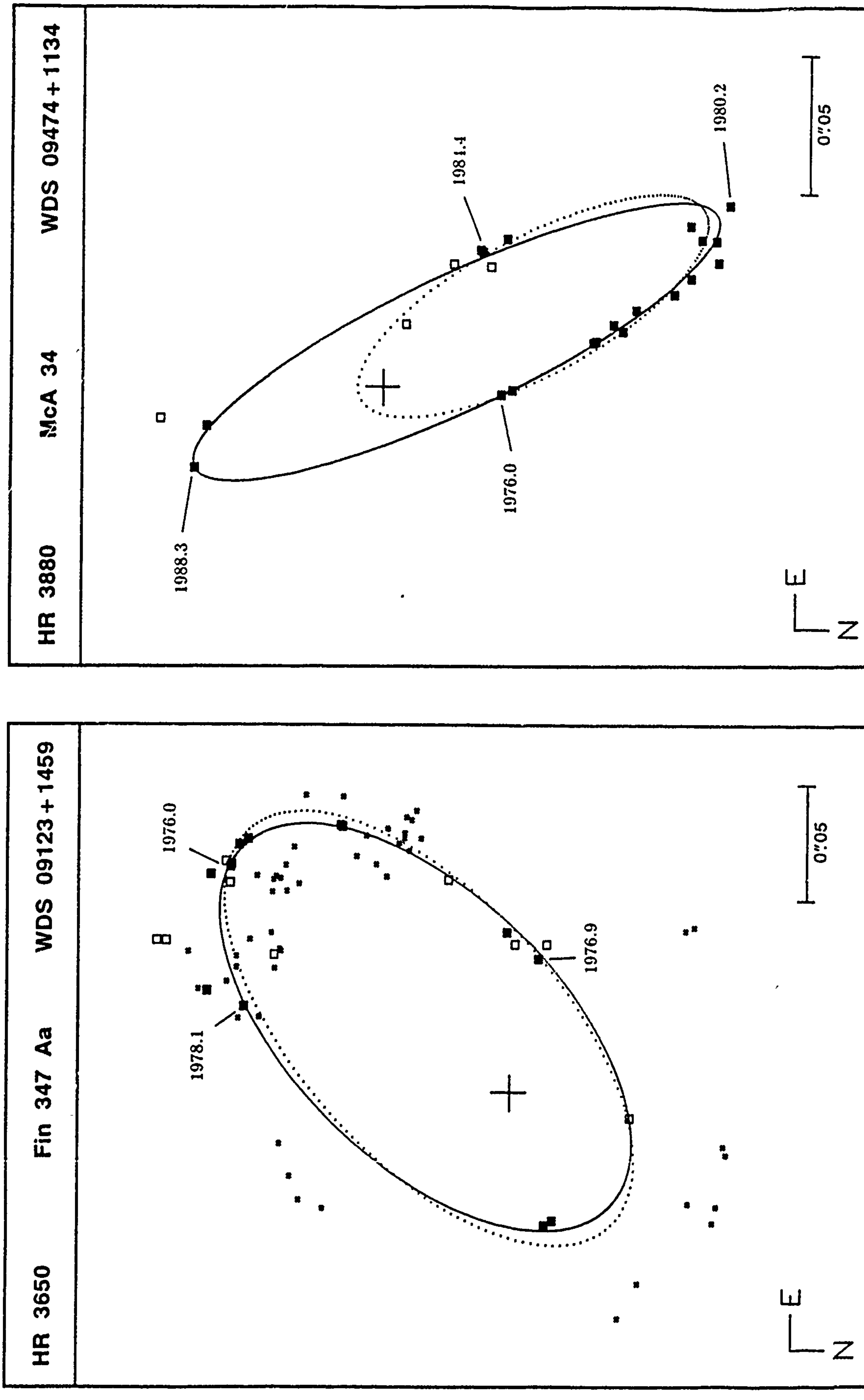

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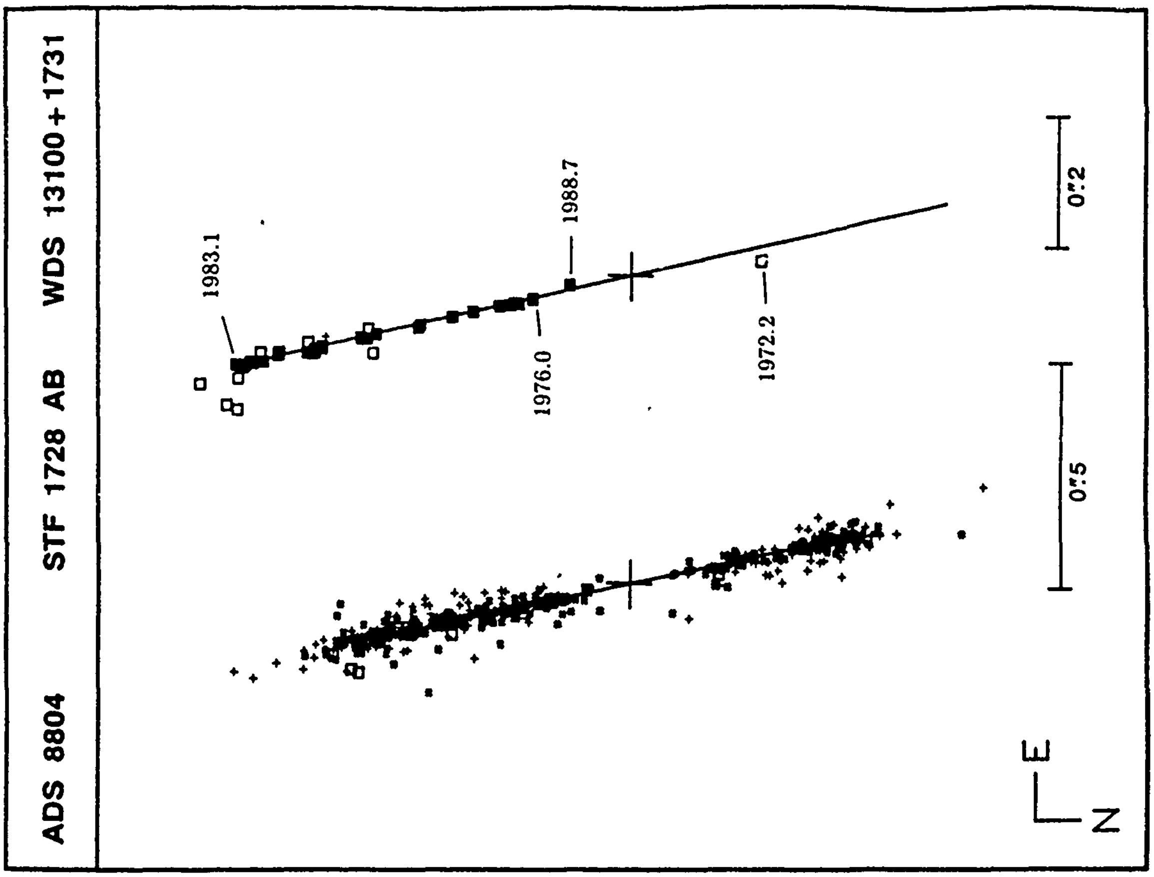


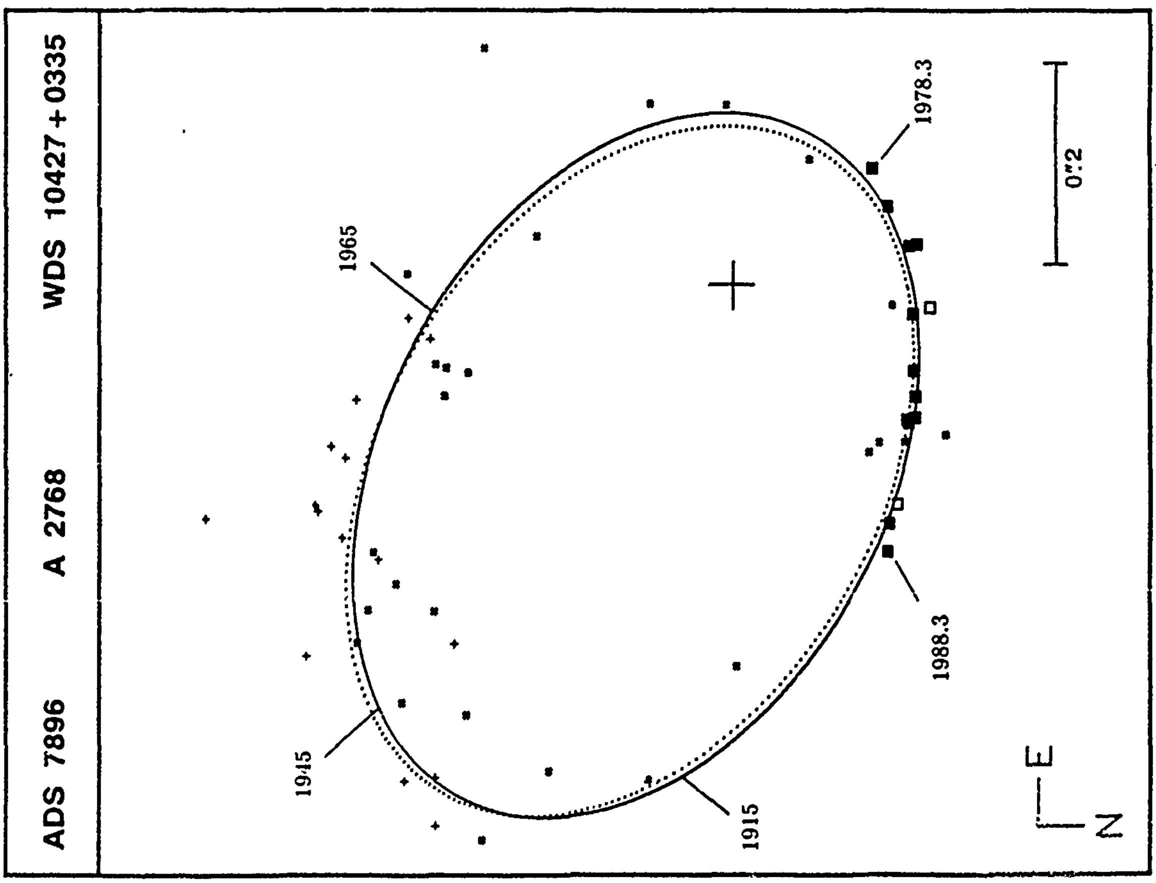
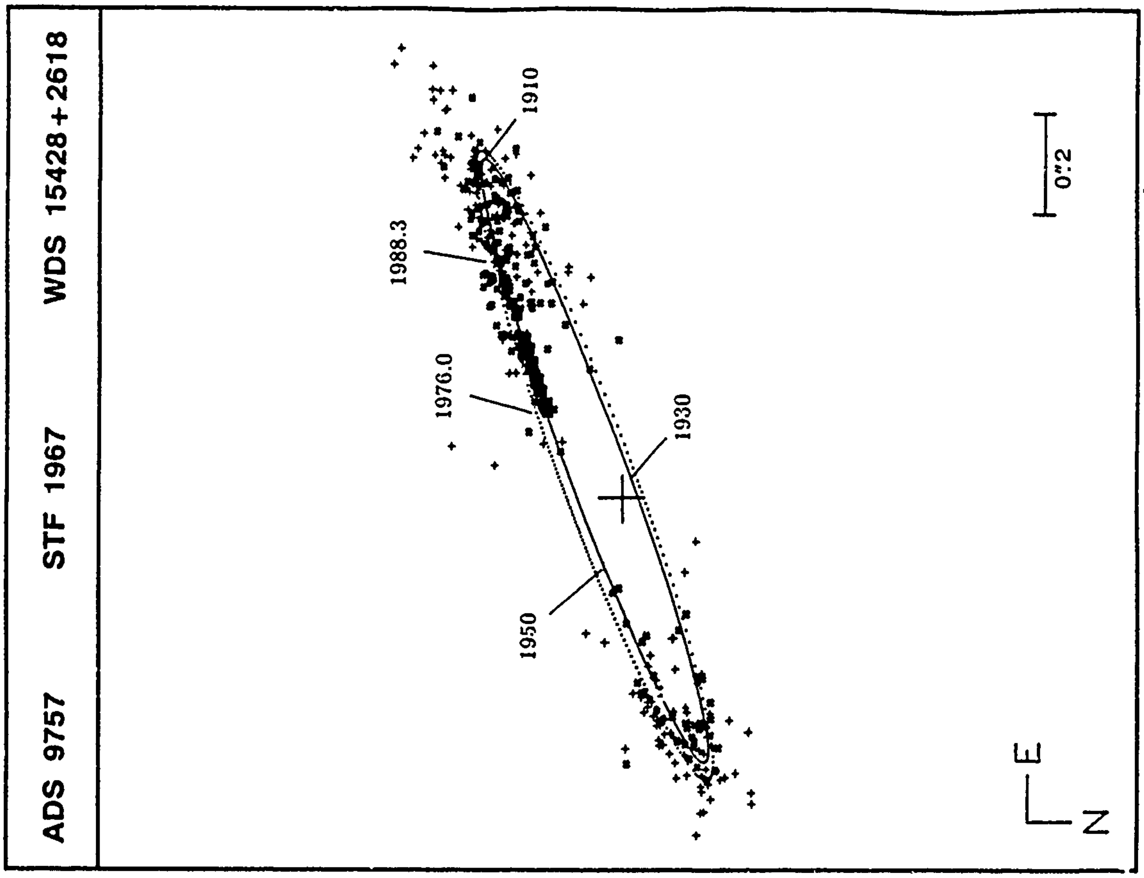


FIG. 1. (continued)



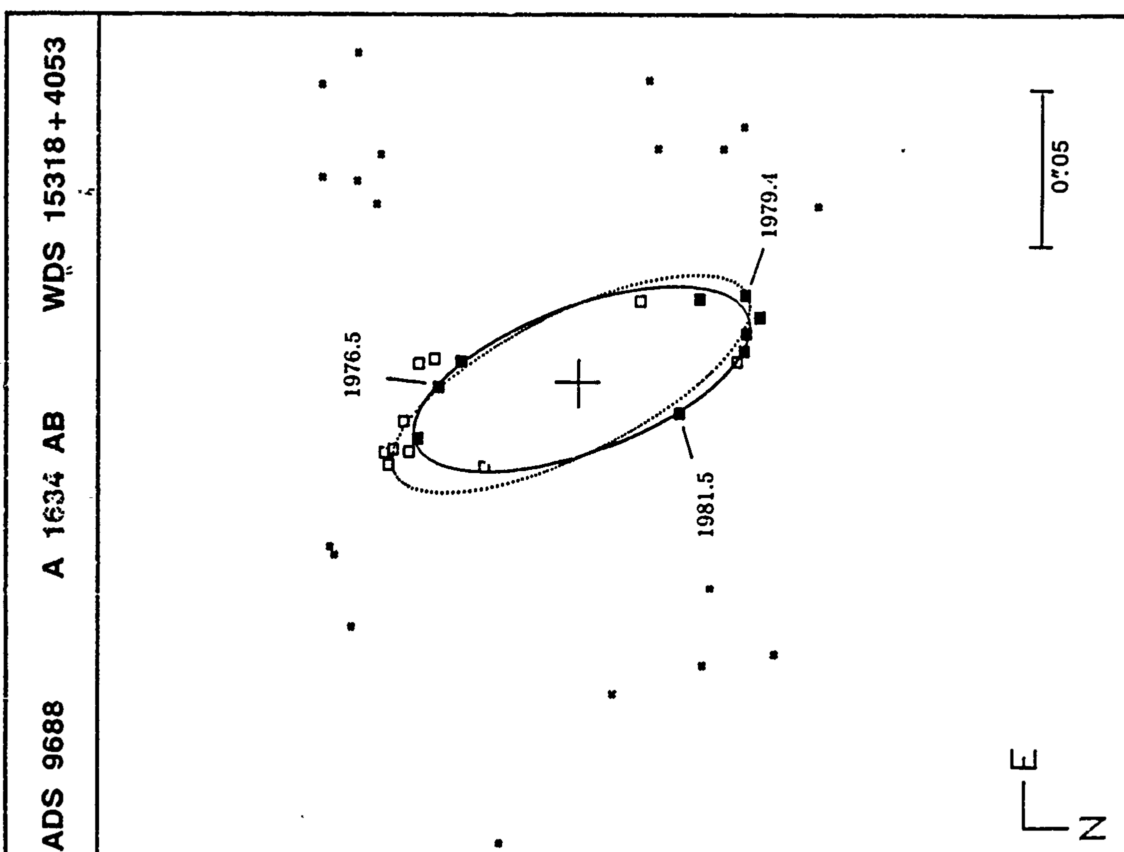


FIG. 1. (continued)

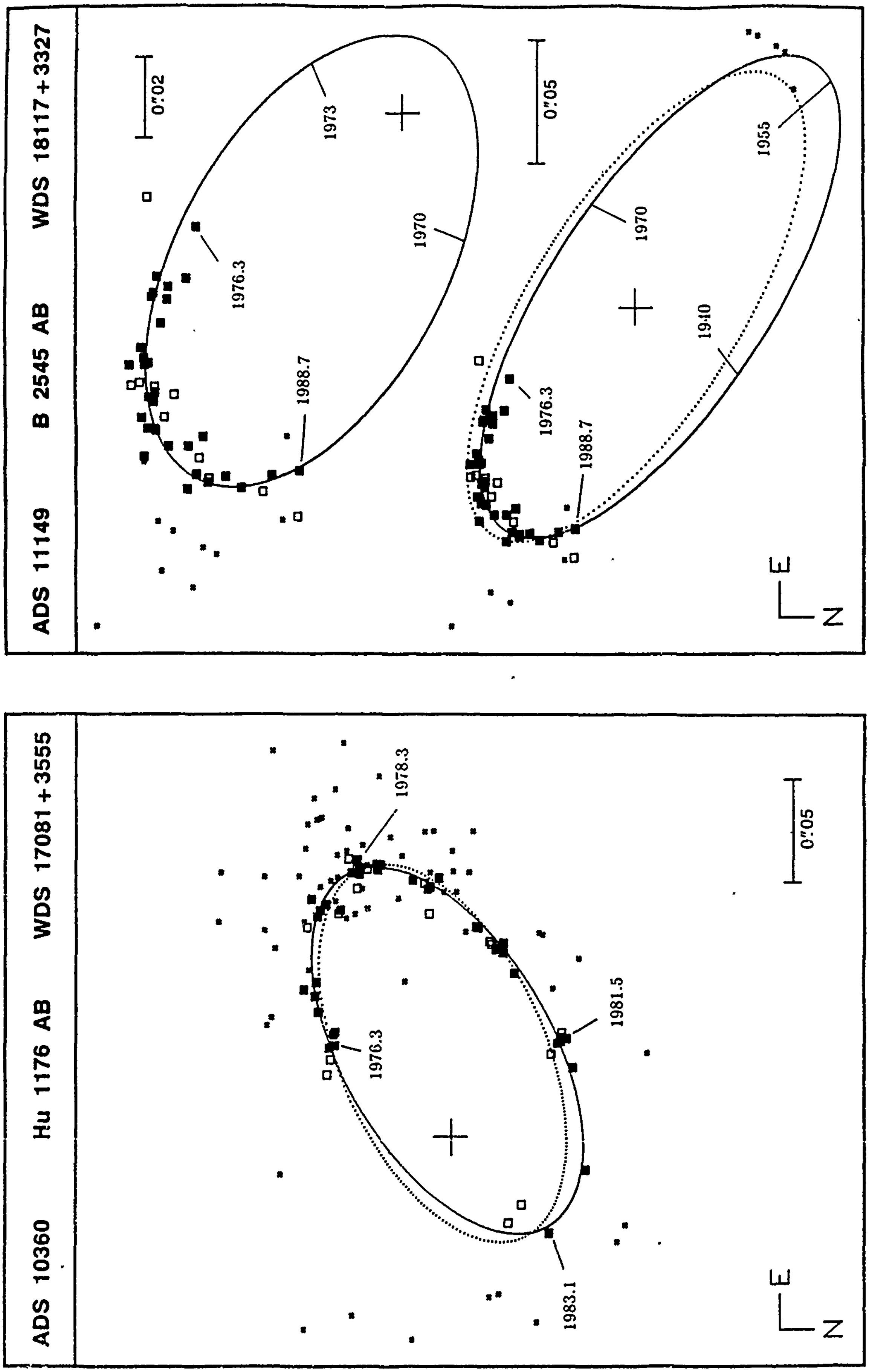


FIG. 1. (continued)

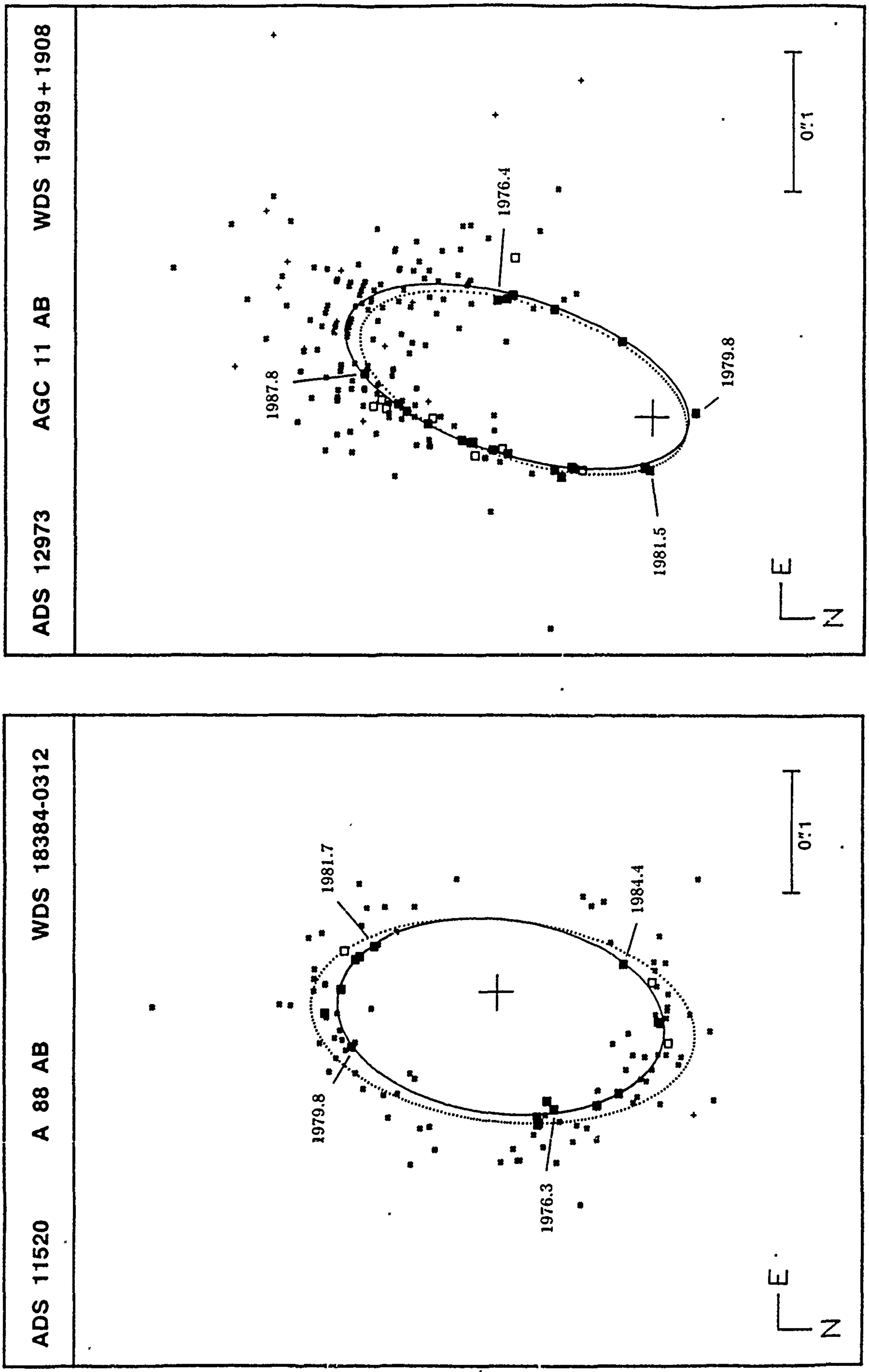


FIG. 1. (continued)

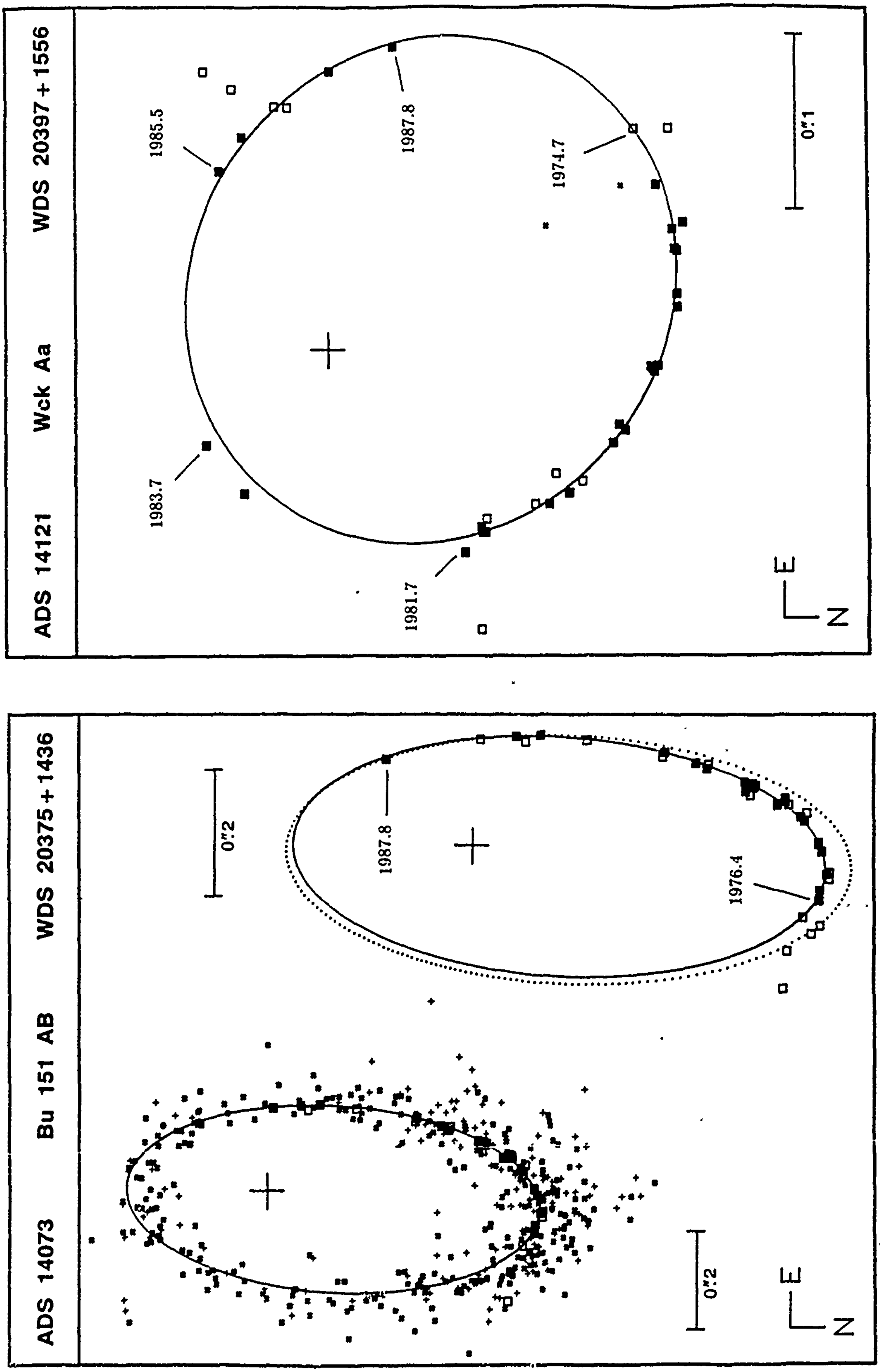


FIG. 1. (continued)

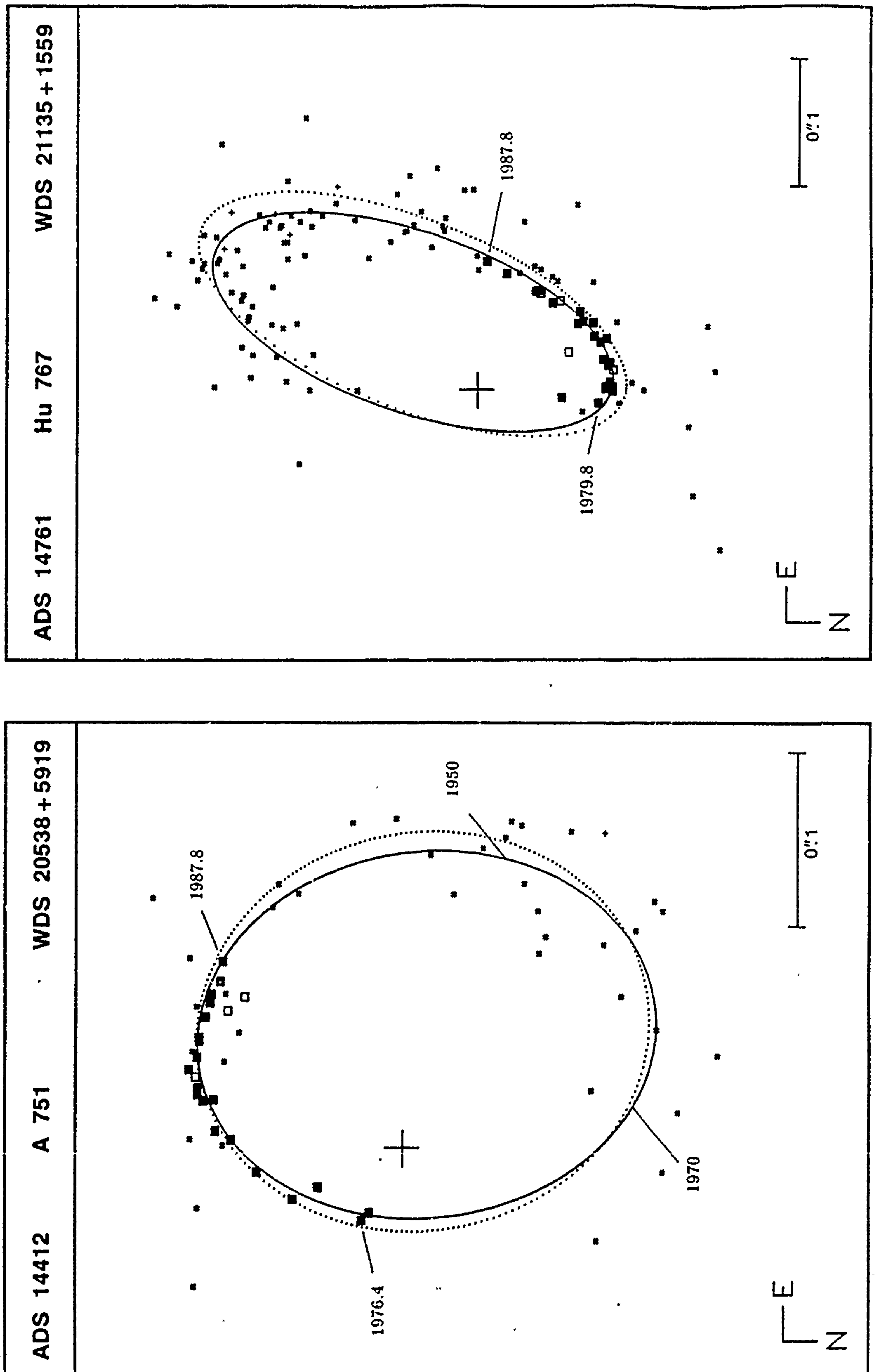


FIG. 1. (continued)

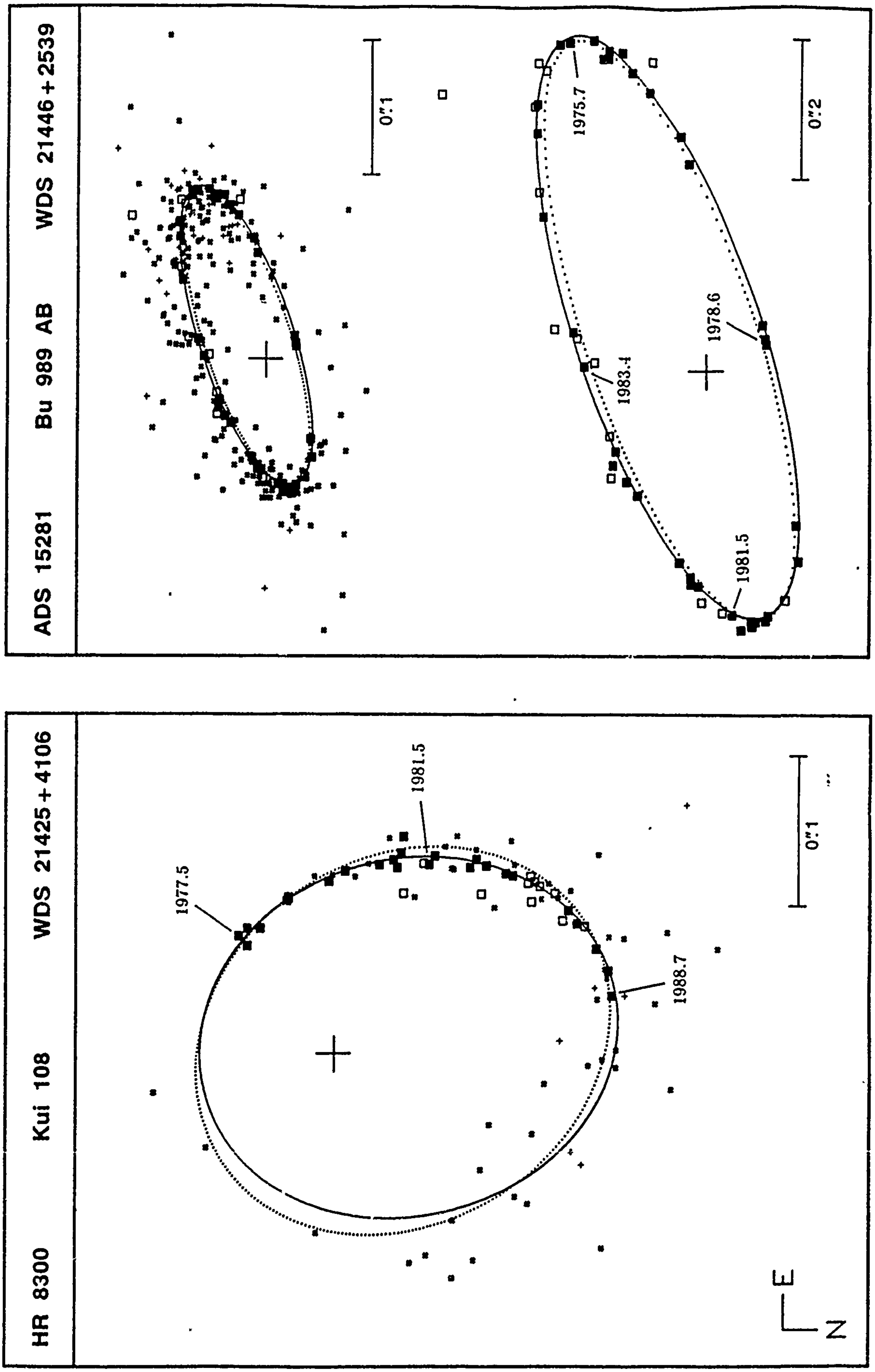
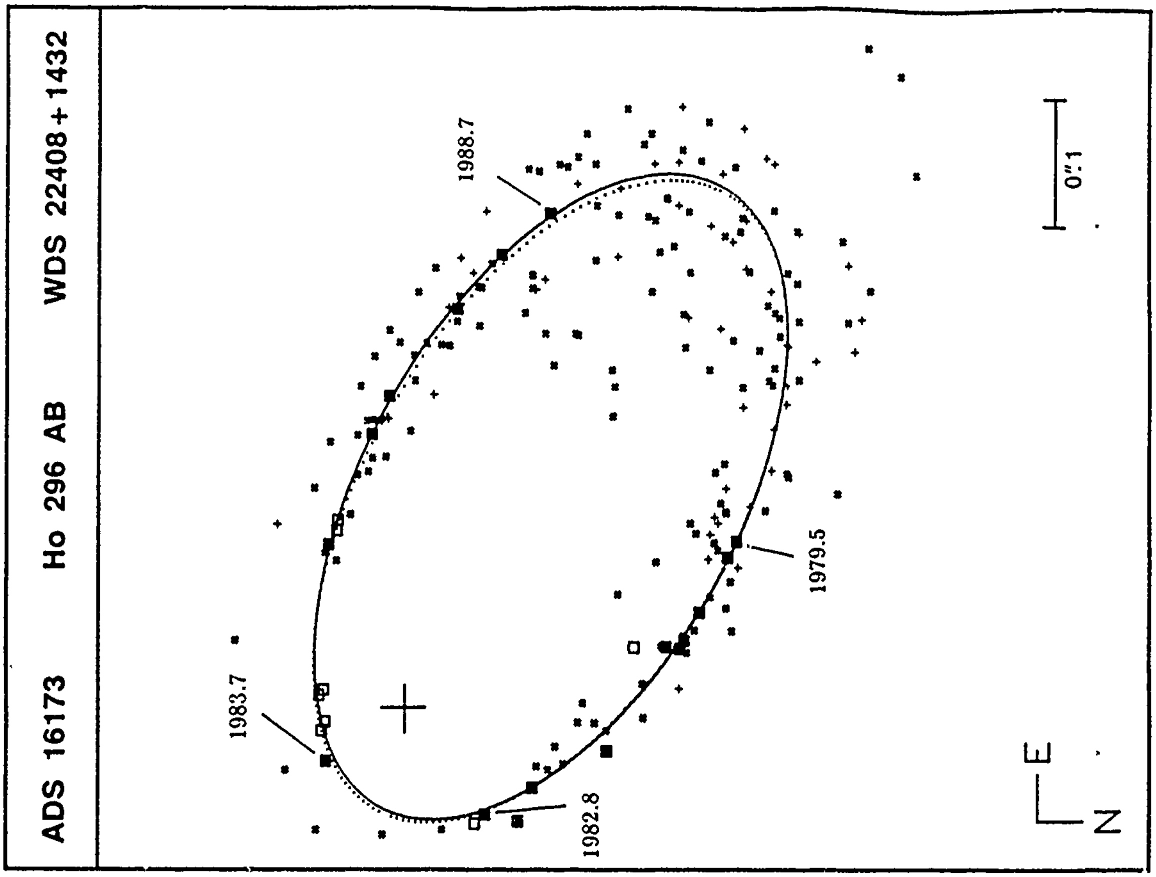


FIG. 1. (continued)



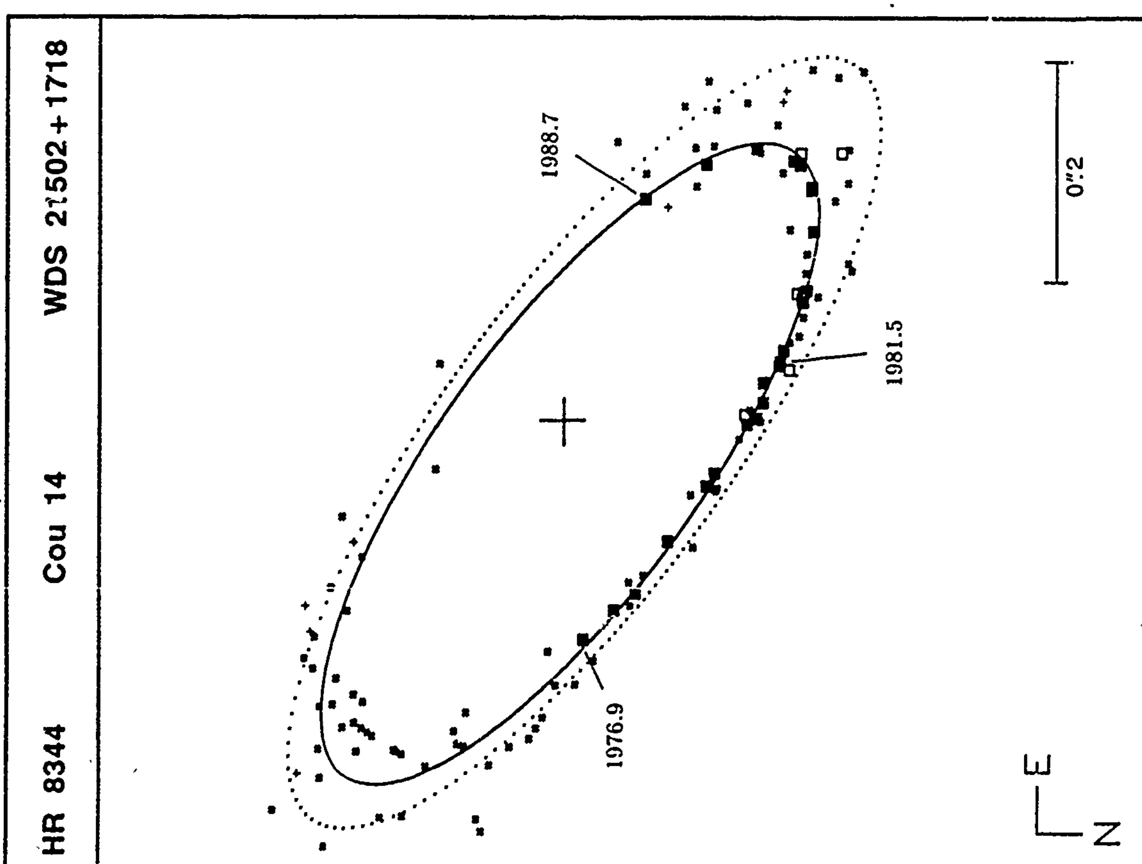


FIG. 1. (continued)

TABLE I. rms residuals to test orbits.

SEPARATE VISUAL AND SPECKLE ORBITS:

Star	Small Visual				Large Visual				CHARA Speckle				Other Speckle			
	σ_θ	σ_ρ	σ_x	σ_y	σ_θ	σ_ρ	σ_x	σ_y	σ_θ	σ_ρ	σ_x	σ_y	σ_θ	σ_ρ	σ_x	σ_y
ADS 490	4.95	0.0394	0.0410	0.0202	7.73	0.0373	0.0344	0.0282	1.56	0.0045	0.0038	0.0062	0.60	0.0050	0.0041	0.0041
ADS 6993	9.92	0.0533	0.0415	0.0508	7.61	0.0365	0.0292	0.0337	0.63	0.0031	0.0029	0.0020	0.97	0.0061	0.0035	0.0066
ADS 8804	4.32	0.0823	0.0364	0.0787	5.69	0.0697	0.0254	0.0691	0.82	0.0051	0.0029	0.0051	2.71	0.0311	0.0294	0.0271
ADS 9757	6.20	0.1096	0.1020	0.0592	3.46	0.0898	0.0822	0.0453	0.52	0.0026	0.0022	0.0032	1.05	0.0099	0.0093	0.0059
ADS 11520	—	—	—	—	11.65	0.0228	0.0207	0.0264	1.17	0.0054	0.0042	0.0042	2.52	0.0074	0.0075	0.0062
ADS 14073	4.27	0.0682	0.0365	0.0648	4.26	0.0588	0.0301	0.0553	0.75	0.0028	0.0069	0.0028	1.46	0.0224	0.0149	0.0215
ADS 15281	16.63	0.0434	0.0470	0.0336	11.64	0.0434	0.0422	0.0275	1.47	0.0027	0.0032	0.0028	4.63	0.0076	0.0105	0.0088
ADS 16173	3.50	0.0382	0.0365	0.0246	4.39	0.0517	0.0436	0.0329	2.11	0.0032	0.0060	0.0036	4.19	0.0114	0.0079	0.0110
Mean	7.11	0.0621	0.0487	0.0474	7.05	0.0513	0.0385	0.0398	1.13	0.0037	0.0040	0.0037	2.27	0.0126	0.0109	0.0114
Weight	0.98	0.68	0.62	0.71	1.0	1.0	1.0	1.0	38.9	192.2	92.6	115.7	9.6	16.6	12.5	12.2
Median	4.95	0.0533	0.0410	0.0508	6.65	0.0476	0.0323	0.0333	1.00	0.0032	0.0035	0.0034	1.99	0.0088	0.0086	0.0077
Weight	1.80	0.80	0.62	0.43	1.0	1.0	1.0	1.0	44.2	221.3	85.2	95.9	11.2	29.3	14.1	18.7

COMBINED VISUAL/SPECKLE ORBITS:

Star	Small Visual				Large Visual				CHARA Speckle				Other Speckle			
	σ_θ	σ_ρ	σ_x	σ_y	σ_θ	σ_ρ	σ_x	σ_y	σ_θ	σ_ρ	σ_x	σ_y	σ_θ	σ_ρ	σ_x	σ_y
ADS 490	4.86	0.0416	0.0433	0.0211	8.39	0.0376	0.0346	0.0293	1.28	0.0037	0.0026	0.0062	0.55	0.0050	0.0040	0.0038
ADS 6993	9.66	0.0601	0.0417	0.0585	9.35	0.0379	0.0303	0.0356	0.61	0.0030	0.0027	0.0021	0.76	0.0031	0.0034	0.0031
ADS 8804	4.42	0.0829	0.0326	0.0803	5.51	0.0716	0.0235	0.0708	0.84	0.0042	0.0030	0.0042	0.44	0.0109	0.0047	0.0107
ADS 9757	5.80	0.1100	0.1014	0.0610	3.10	0.0898	0.0823	0.0443	0.69	0.0031	0.0024	0.0043	1.46	0.0079	0.0093	0.0051
ADS 11520	—	—	—	—	12.11	0.0295	0.0223	0.0308	1.30	0.0054	0.0043	0.0043	2.47	0.0071	0.0073	0.0058
ADS 14073	6.18	0.0752	0.0390	0.0726	7.35	0.0651	0.0353	0.0639	0.65	0.0026	0.0058	0.0025	1.31	0.0061	0.0107	0.0054
ADS 15281	14.10	0.0477	0.0471	0.0332	11.69	0.0433	0.0406	0.0287	1.57	0.0027	0.0033	0.0035	2.64	0.0060	0.0072	0.0043
ADS 16173	3.45	0.0360	0.0351	0.0233	4.40	0.0538	0.0457	0.0338	1.14	0.0034	0.0028	0.0034	3.09	0.0034	0.0047	0.0031
Mean	6.92	0.0648	0.0486	0.0500	7.74	0.0536	0.0393	0.0422	1.01	0.0035	0.0034	0.0038	1.59	0.0062	0.0064	0.0052
Weight	1.25	0.68	0.65	0.71	1.0	1.0	1.0	1.0	58.7	234.5	133.6	123.3	23.7	74.7	37.7	65.9
Median	5.80	0.0601	0.0417	0.0585	7.87	0.0486	0.0376	0.0347	0.99	0.0033	0.0029	0.0039	1.39	0.0061	0.0060	0.0047
Weight	1.84	0.65	0.81	0.35	1.0	1.0	1.0	1.0	63.2	216.9	168.1	79.2	32.1	63.5	39.3	54.5

TABLE II. Orbital elements.

WDS	ADS	Name	P	a″	i	Ω	T	e	ω
00352−0336	490	Ho 212 AB	$6\overset{\rm y}{.}89$ ±0.18	$0\overset{\prime\prime}{.}240$ ±0.010	$49\overset{\circ}{.}0$ ±6.1	$149\overset{\circ}{.}2$ ±14.2	1973.389 ± 0.066	0.767 ±0.090	$283\overset{\circ}{.}5$ ±14.2
01233+5808	1105	STF 115 AB	209.5 ±7.8	0.805 ±0.018	99.6 ±5.7	138.7 ± 1.5	1984.88 ± 0.18	0.920 ±0.007	133.1 ± 1.5
01512+2439	1473	Ho 311	119.3 ±6.2	0.2980 ±0 0062	52.8 ±1.7	212.8 ± 3.9	1982.72 ± 0.40	0.888 ±0.016	142.0 ± 3.9
02157+2503	—	Cou 79	24.54 ±0.75	0.2470 ±0.0014	104.15 ±0.97	235.89 ± 0.61	1986.182 ± 0.057	0.684 ±0.006	82.57 ± 0.61
02396−1153	—	Fin 312	2.654 ±0.002	0.1055 ±0.0012	21.3 ±1.4	279.3 ±18.4	1956.603 ± 0.007	0.228 ±0.020	31.1 ±18.4
06383+2859	—	McA 27	22.32 ±0.15	0.1463 ±0.0016	112.1 ±1.0	115.86 ± 0.29	1976.260 ± 0.043	0.595 ±0.002	307.87 ± 0.29
07352+3058	6185	STT 175 AB	213.1 ±5.8	0.5493 ±0.0029	92.48 ±0.48	149.49 ± 0.84	1979.11 ± 0.21	0.693 ±0.007	313.22 ± 0.84
07518−1352	6420	Bu 101	23.34 ±0.17	0.573 ±0.010	79.68 ±0.06	102.5 ± 1.6	1962.381 ± 0.039	0.735 ±0.016	71.4 ± 1.6
08468+0625	6993	SP AB	15.05 ±0.20	0.2543 ±0.0038	49.92 ±0.38	108.1 ± 1.8	1976.179 ± 0.042	0.653 ±0.003	265.8 ± 1.8
09008+4148	—	Kui 37 AB	21.783 ±0.090	0.6604 ±0.0018	129.84 ±0.01	205.93 ± 0.54	1972.318 ± 0.010	0.153 ±0.004	39.25 ± 0.54
09123+1459	—	Fin 347 Aa	2.703 ±0.022	0.1161 ±0.0018	124.1 ±2.7	317.0 ± 5.2	1979.975 ± 0.065	0.418 ±0.071	348.5 ± 5.2
09474+1134	—	McA 34	15.167 ±0.090	0.1120 ±0.0002	76.57 ±0.66	203.80 ± 0.48	1973.68 ± 0.25	0.321 ±0.010	24.44 ± 0.48
10427+0335	7896	A 2768	80.56 ±0.30	0.3778 ±0.0014	145.92 ±0.78	56.8 ± 1.9	1976.674 ± 0.030	0.546 ±0.001	355.3 ± 1.9
13100+1731	8804	STF 1728 AB	25.804 ±0.055	0.6684 ±0.0013	90.06 ±0.05	192.34 ± 0.24	1963.468 ± 0.021	0.497 ±0.012	101.08 ± 0.24
15318+4053	9688	A 1634 AB	8.484 ±0.052	0.0602 ±0.0002	114.6 ±3.0	199.1 ± 3.7	1965.94 ± 0.21	0.021 ±0.046	302.6 ± 3.7
15428+2618	9757	STF 1967	92.94 ±0.58	0.7353 ±0.0041	94.70 ±0.84	111.25 ± 0.61	1931.66 ± 0.23	0.484 ±0.020	105.24 ± 0.61
17081+3555	10360	Hu 1176 AB	8.129 ±0.014	0.1118 ±0.0001	120.49 ±0.09	129.44 ± 0.25	1975.483 ± 0.007	0.539 ±0.003	235.69 ± 0.25
18117+3327	11149	B 2545	23.9 ±1.0	0.0620 ±0.0005	37.9 ±5.8	244.1 ±19.0	1971.81 ± 0.81	0.706 ±0.055	172.1 ±19.0
			58.39 ±0.52	0.1155 ±0.0006	66.6 ±2.9	234.4 ± 1.2	1975.54 ± 0.16	0.153 ±0.027	302.4 ± 1.2
18384−0312	11520	A 88 AB	12.133 ±0.019	0.1479 ±0.0001	122.85 ±0.01	173.84 ± 0.12	1970.801 ± 0.007	0.249 ±0.002	81.22 ± 0.12
19489+1908	12973	AGC 11 AB	23.22 ±0.96	0.1359 ±0.0016	133.19 ±0.85	340.7 ± 1.4	1979.869 ± 0.035	0.792 ±0.005	355.1 ± 1.4
20375+1436	14073	Bu 151 AB	26.598 ±0.004	0.4473 ±0.0001	63.13 ±0.01	177.09 ± 0.05	1963.225 ± 0.009	0.328 ±0.002	351.32 ± 0.05
20397+1556	14121	Wck Aa	17.09 ±0.16	0.1595 ±0.0003	161.6 ±1.8	279.4 ± 4.0	1983.885 ± 0.030	0.466 ±0.005	71.4 ± 4.0
20538+5919	14412	A 751	57.9 ±1.5	0.1782 ±0.0027	126.7 ±2.6	179.2 ± 3.4	1976.12 ± 0.27	0.621 ±0.013	277.2 ± 3.4
21135+1559	14761	Hu 767	33.75 ±0.23	0.2067 ±0.0017	67.95 ±0.52	167.79 ± 0.67	1944.55 ± 0.11	0.618 ±0.007	120.19 ± 0.67
21425+4106	—	Kui 108	26.51 ±0.48	0.149 ±0.014	149.4 ±5.2	191.4 ± 9.7	1975.23 ± 0.12	0.361 ±0.009	359.7 ± 9.7
21446+2539	15281	Bu 989 AB	11.60 ±0.12	0.2362 ±0.0004	108.04 ±0.50	288.85 ± 0.60	1979.207 ± 0.027	0.313 ±0.009	304.17 ± 0.60
21502+1718	—	Cou 14	26.132 ±0.056	0.3664 ±0.0043	70.30 ±1.00	231.80 ± 0.11	1963.887 ± 0.025	0.239 ±0.003	252.08 ± 0.11
22408+1432	16173	Ho 296 AB	20.83 ±0.15	0.2907 ±0.0002	140.12 ±0.02	252.37 ± 0.23	1983.557 ± 0.004	0.738 ±0.001	23.28 ± 0.23

Table III. Ephemerides.

Date	ADS 490		Fin 312		Fin 347		ADS 9688		ADS 10360	
1989.00	230°0	0″236	53°3	0″101	161°7	0″130	11°0	0″058	62°7	0″086
1989.25	235.4	0.247	82.2	0.117	150.4	0.154	5.9	0.054	54.0	0.079
1989.50	240.4	0.258	105.2	0.126	141.4	0.163	359.8	0.049	44.0	0.074
1989.75	245.0	0.267	126.3	0.128	132.6	0.157	352.1	0.043	32.7	0.071
1990.00	249.3	0.274	148.1	0.122	122.0	0.134	341.6	0.036	20.4	0.068
1990.25	253.4	0.281	173.0	0.112	104.4	0.094	326.4	0.030	7.5	0.068
1990.50	257.4	0.286	203.4	0.101	54.8	0.051	304.8	0.025	354.8	0.069
1990.75	261.2	0.290	241.1	[illegible]	331.8	0.064	278.9	0.025	342.4	0.070
1991.00	264.9	0.292	287.0	0.083	278.9	0.060	255.8	0.028	330.2	0.070
1991.25	268.6	0.293	340.4	0.079	211.5	0.065	239.1	0.034	317.5	0.066
1991.50	272.3	0.292	29.9	0.090	175.7	0.101	227.6	0.041	301.4	0.055
1991.75	276.1	0.289	65.4	0.107	159.2	0.135	219.3	0.047	271.3	0.036
1992.00	279.9	0.284	91.5	0.121	148.6	0.157	212.8	0.052	203.7	0.030
1992.25	284.0	0.276	113.4	0.128	139.8	0.163	207.4	0.056	162.0	0.051
1992.50	288.3	0.266	134.5	0.126	130.9	0.154	202.6	0.059	146.2	0.074
1992.75	293.0	0.251	157.2	0.119	119.5	0.128	198.1	0.060	137.6	0.093
1993.00	298.4	0.233	183.9	0.108	99.1	0.086	193.5	0.058	131.8	0.108
1993.25	304.9	0.208	217.0	0.096	37.4	0.048	188.6	0.056	127.2	0.119
1993.50	313.6	0.174	257.8	0.087	321.9	0.067	183.0	0.052	123.3	0.128
1993.75	327.9	0.124	307.0	0.080	266.6	0.058	176.3	0.046	119.9	0.134
1994.00	20.4	0.047	0.9	0.082	202.1	0.070	167.7	0.040	116.7	0.137
1994.25	151.3	0.087	45.1	0.096	171.8	0.108	155.9	0.034	113.6	0.139
1994.50	177.9	0.131	76.2	0.113	157.0	0.140	139.3	0.029	110.5	0.139
1994.75	192.9	0.159	100.2	0.125	146.9	0.159	117.2	0.026	107.5	0.138
1995.00	203.9	0.181	121.5	0.128	138.2	0.163	93.0	0.026	104.3	0.136

Date	ADS 6993		McA 34		ADS 11520		ADS 14121		ADS 15281	
1989.0	254°9	0″215	212°0	0″065	279°7	0″103	61°8	0″202	97°7	0″185
1989.5	263.8	0.197	222.5	0.047	263.0	0.100	56.4	0.208	87.1	0.128
1990.0	274.9	0.171	248.9	0.027	246.1	0.102	51.4	0.214	57.0	0.067
1990.5	291.2	0.132	316.2	0.023	230.6	0.109	46.6	0.218	338.0	0.065
1991.0	328.9	0.074	352.9	0.042	217.2	0.118	41.9	0.221	305.5	0.122
1991.5	65.1	0.075	5.2	0.064	205.9	0.128	37.3	0.222	293.4	0.168
1992.0	101.6	0.136	11.3	0.084	196.1	0.136	32.8	0.223	285.5	0.186
1992.5	116.9	0.179	15.0	0.102	187.2	0.140	28.3	0.223	278.1	0.182
1993.0	126.9	0.208	17.8	0.117	178.3	0.137	23.7	0.222	269.6	0.162
1993.5	134.8	0.229	20.0	0.128	168.7	0.128	19.1	0.220	257.9	0.134
1994.0	141.5	0.244	21.8	0.136	156.6	0.109	14.4	0.217	239.9	0.106
1994.5	147.6	0.254	23.5	0.141	138.2	0.085	9.5	0.212	212.4	0.090
1995.0	153.2	0.262	25.1	0.144	105.5	0.063	4.4	0.207	181.2	0.095
1995.5	158.6	0.267	26.7	0.143	60.7	0.065	359.0	0.201	158.2	0.119
1996.0	163.8	0.271	28.3	0.140	29.8	0.087	353.2	0.194	144.1	0.151
1996.5	168.9	0.273	30.1	0.135	12.6	0.113	347.0	0.186	135.0	0.184
1997.0	174.0	0.274	32.0	0.127	1.4	0.133	340.1	0.176	128.6	0.215
1997.5	179.0	0.274	34.2	0.116	352.7	0.146	332.5	0.166	123.7	0.240
1998.0	184.0	0.274	36.9	0.104	345.0	0.151	323.7	0.155	119.6	0.259
1998.5	189.1	0.272	40.4	0.090	337.5	0.150	313.5	0.142	115.9	0.269
1999.0	194.2	0.271	45.2	0.075	329.6	0.144	301.1	0.128	112.5	0.270
1999.5	199.4	0.269	52.8	0.058	320.8	0.135	285.7	0.114	108.8	0.258
2000.0	204.6	0.266	66.3	0.042	310.6	0.124	265.8	0.099	104.7	0.234

TABLE III. (continued)

Date	Cou 79		McA 27		ADS 6420		Kui 37		ADS 8804	
1989	48°.5	0″.194	315°.8	0″.176	288°.5	0″.514	256°.9	0″.487	190°.4	0″.011
1990	44.6	0.207	312.6	0.183	290.7	0.545	239.2	0.532	12.4	0.250
1991	40.9	0.209	309.5	0.186	292.7	0.554	224.2	0.569	12.3	0.423
1992	37.2	0.204	306.5	0.186	294.7	0.548	210.6	0.581	12.3	0.503
1993	33.1	0.194	303.4	0.180	296.9	0.529	196.6	0.556	12.3	0.519
1994	28.6	0.182	300.0	0.168	299.2	0.502	180.2	0.497	12.3	0.494
1995	23.4	0.167	295.9	0.149	301.8	0.466	158.4	0.423	12.2	0.442
1996	17.0	0.151	290.1	0.119	304.9	0.425	129.2	0.377	12.2	0.373
1997	9.1	0.135	278.9	0.076	308.7	0.379	97.8	0.398	12.2	0.292
1998	359.3	0.120	218.3	0.025	313.6	0.330	73.2	0.473	12.1	0.203
1999	346.9	0.108	123.7	0.060	320.3	0.279	56.1	0.565	11.8	0.110
2000	332.2	0.101	103.0	0.078	329.9	0.231	43.7	0.646	8.0	0.014
2001	316.3	0.100	85.2	0.074	344.2	0.188	33.7	0.704	193.1	0.082
2002	300.9	0.105	63.7	0.066	5.2	0.159	25.0	0.733	192.7	0.176
2003	287.5	0.115	38.8	0.064	30.7	0.156	16.5	0.735	192.6	0.267
2004	276.6	0.128	15.5	0.071	53.4	0.177	7.8	0.711	192.5	0.354
2005	267.7	0.141	357.9	0.084	69.7	0.214	358.2	0.665	192.5	0.434
2006	260.4	0.154	345.6	0.100	81.0	0.253	346.9	0.605	192.4	0.505
2007	254.0	0.162	336.7	0.117	89.6	0.280	333.0	0.541	192.4	0.566
2008	248.1	0.163	330.1	0.134	97.7	0.262	315.5	0.486	192.4	0.612
2009	241.6	0.148	324.9	0.149	120.5	0.078	294.7	0.457	192.4	0.641
2010	231.3	0.097	320.6	0.162	279.2	0.253	272.8	0.462	192.4	0.646

Date	ADS 11149 (Short Period)		ADS 11149 (Long Period)		ADS 12973		ADS 14073		ADS 14412	
1989	254°.6	0″.090	254°.6	0″.091	169°.2	0″.233	161°.5	0″.271	131°.3	0″.157
1990	258.9	0.083	258.8	0.085	167.0	0.239	175.4	0.300	127.6	0.158
1991	264.2	0.074	263.6	0.079	165.0	0.242	188.3	0.292	124.0	0.160
1992	271.1	0.063	269.1	0.073	162.9	0.243	203.8	0.253	120.3	0.161
1993	281.4	0.050	275.6	0.068	160.9	0.241	225.9	0.208	116.8	0.162
1994	300.1	0.034	283.3	0.062	158.8	0.236	256.8	0.187	113.3	0.163
1995	348.8	0.020	292.4	0.057	156.6	0.227	287.1	0.211	109.8	0.164
1996	84.6	0.019	303.0	0.054	154.1	0.216	308.0	0.266	106.4	0.165
1997	153.4	0.027	314.7	0.052	151.4	0.201	321.1	0.332	103.0	0.166
1998	183.0	0.041	326.9	0.051	148.1	0.183	329.9	0.396	99.7	0.167
1999	197.7	0.054	338.7	0.053	144.1	0.160	336.3	0.454	96.3	0.168
2000	206.8	0.066	349.5	0.057	138.4	0.132	341.4	0.504	93.1	0.169
2001	213.3	0.075	358.8	0.061	129.1	0.097	345.6	0.543	89.9	0.170
2002	218.4	0.084	6.7	0.067	106.7	0.054	349.3	0.571	86.7	0.171
2003	222.7	0.091	13.3	0.073	357.7	0.028	352.7	0.587	83.5	0.172
2004	226.4	0.096	18.9	0.079	236.5	0.044	356.0	0.592	80.5	0.174
2005	229.7	0.100	23.6	0.086	204.3	0.084	359.4	0.584	77.4	0.175
2006	232.9	0.103	27.7	0.092	192.5	0.119	2.9	0.564	74.4	0.176
2007	235.8	0.105	31.2	0.098	185.8	0.148	6.7	0.531	71.4	0.177
2008	238.8	0.105	34.4	0.104	181.1	0.173	11.2	0.486	68.5	0.178
2009	241.7	0.105	37.3	0.109	177.5	0.193	16.7	0.429	65.6	0.180
2010	244.7	0.103	39.9	0.113	174.6	0.209	24.2	0.361	62.8	0.181

TABLE III. (continued)

Date	ADS 14761		Kui 108		Cou 14		ADS 16173	
1989	100°.7	0″.121	8°.7	0″.203	72°.9	0″.200	71°.1	0″.421
1990	109.0	0.133	2.7	0.200	97.2	0.125	67.2	0.451
1991	115.9	0.146	356.5	0.196	154.9	0.098	63.6	0.472
1992	121.7	0.160	350.0	0.189	197.2	0.157	60.3	0.485
1993	126.5	0.173	342.8	0.179	213.5	0.235	57.2	0.490
1994	130.7	0.186	334.8	0.168	222.0	0.301	54.0	0.489
1995	134.4	0.198	325.5	0.155	227.7	0.348	50.8	0.480
1996	137.6	0.210	314.4	0.141	232.3	0.375	47.4	0.464
1997	140.5	0.220	300.7	0.126	236.5	0.385	43.7	0.441
1998	143.2	0.229	283.6	0.113	240.6	0.379	39.5	0.411
1999	145.7	0.236	262.5	0.103	245.1	0.359	34.6	0.373
2000	148.0	0.242	237.9	0.097	250.1	0.329	28.5	0.328
2001	150.3	0.245	211.6	0.095	256.4	0.291	20.1	0.274
2002	152.5	0.247	184.9	0.095	264.8	0.248	7.1	0.211
2003	154.8	0.245	158.3	0.096	276.7	0.205	342.1	0.143
2004	157.0	0.241	132.7	0.099	294.4	0.169	279.1	0.088
2005	159.4	0.233	109.8	0.107	318.6	0.151	148.5	0.089
2006	162.0	0.221	90.8	0.119	344.5	0.159	103.2	0.189
2007	165.0	0.204	75.5	0.134	5.0	0.189	88.8	0.273
2008	168.6	0.180	63.2	0.148	19.0	0.229	80.7	0.338
2009	173.7	0.147	53.1	0.162	28.8	0.269	75.0	0.389
2010	182.4	0.103	44.4	0.174	36.2	0.303	70.4	0.427

Date	ADS 1105		ADS 1473		ADS 6185		ADS 7896		ADS 9757	
1990	261°.9	0″.061	144°.4	0″.130	147°.0	0″.206	293°.0	0″.332	118°.1	0″.587
1992	222.8	0.065	151.6	0.158	146.2	0.194	285.7	0.366	117.3	0.625
1994	197.3	0.090	156.7	0.185	145.3	0.180	279.6	0.399	116.6	0.659
1996	184.0	0.122	160.5	0.209	144.2	0.163	274.5	0.429	115.9	0.689
1998	176.4	0.157	163.6	0.233	142.8	0.144	269.9	0.456	115.3	0.713
2000	171.5	0.192	166.1	0.255	141.1	0.125	265.9	0.481	114.7	0.731
2002	168.2	0.227	168.2	0.275	138.6	0.104	262.2	0.503	114.2	0.741
2004	165.7	0.261	170.1	0.295	135.0	0.084	258.9	0.522	113.7	0.744
2006	163.8	0.294	171.7	0.313	129.0	0.063	255.7	0.539	113.1	0.738
2008	162.3	0.326	173.1	0.330	117.5	0.044	252.8	0.553	112.5	0.721
2010	161.0	0.357	174.4	0.346	91.4	0.029	249.9	0.564	111.9	0.692
2012	160.0	0.388	175.6	0.361	43.7	0.026	247.2	0.573	111.3	0.647
2014	159.1	0.418	176.7	0.376	11.1	0.039	244.5	0.579	110.5	0.586
2016	158.3	0.447	177.7	0.389	357.1	0.058	241.9	0.583	109.5	0.504
2018	157.6	0.475	178.7	0.401	350.1	0.078	239.3	0.583	108.0	0.399
2020	157.0	0.502	179.6	0.413	346.0	0.099	236.7	0.581	105.2	0.270
2022	156.5	0.529	180.5	0.424	343.4	0.121	234.1	0.577	96.0	0.120
2024	156.0	0.554	181.3	0.434	341.5	0.142	231.4	0.570	322.9	0.059
2026	155.5	0.580	182.0	0.443	340.1	0.162	228.6	0.560	298.5	0.211
2028	155.1	0.604	182.8	0.452	339.0	0.183	225.7	0.547	294.4	0.343
2030	154.7	0.628	183.5	0.459	338.2	0.204	222.7	0.531	292.4	0.441

creased to a predicted closest apparent approach of 0".012 in 1985.15, and will remain under 0".1 until mid-1994.

WDS 01512+2439=ADS 1473=Ho 311. This 119 yr period system has completed nearly one full revolution since its discovery in 1890. It was first measured by speckle in 1978 at 0".13 and reached periastron in 1982.7. The pair was unresolved by Bonneau *et al.* (1984) in 1983.9 (separation <0".07), at which time the orbit predicted a separation of 0".05. Although speckle data were able to bracket the time of periastron passage, additional data are needed before a more definitive orbit can be derived.

WDS 02157+2503=Cou 79. Speckle data cover only half of this 25 yr period, but serve to define the orbit fairly well. The differences in this orbit compared to that of Couteau (1987—also plotted) are due to different weighting methods and to additional speckle data in the first quadrant not available to Couteau.

WDS 02396−1153=Fin 312. This orbit was based solely on speckle data, which cover more than four revolutions. The visual data for this close pair, nearly all obtained by Finsen, differ quite noticeably from the speckle data; Finsen (1970) may have applied some systematic correction to his data in calculating this published orbit, as evidenced by the disparity between his data and his published orbit.

WDS 06383+2859=McA 27. Tokovinin's (1986) orbital elements were derived before the last several data points were obtained. While our orbit clearly fits these data better, it must be considered preliminary until further observations are obtained.

WDS 07352+3058=ADS 6185=STT 175. This long-period, highly inclined system was discovered by Otto Struve in 1842 at $\rho \approx 0''.5$. The separation was smaller by a factor of 10 by 1976.9, when first observed by speckle shortly after closest apparent separation. Periastron occurred in 1979.1, then the system opened to 0".20 by early 1986. It is now starting to close in again; the orbital elements predict that the pair will close to 0".025 by the year 2010. The published orbit by Baize (1986) predicts a period of only 180 yr, while that of Tokovinin (1986—shown here) gives a period of 219.1 yr, close to our 213.1 yr period. Rms residuals for both these published orbits are compared to our orbit in Table IV.

WDS 07518−1352=ADS 6420=Bu 101. This system was observed by speckle over the period 1975 through early 1983, but unfortunately was largely skipped over until 1987. The orbital elements given here were determined using the speckle data alone, after deriving a period based on all visual and speckle data. Periastron occurred in mid-1985, while a closest apparent separation of 0".03 was predicted for 1985.9. By 1991, ρ should increase to its maximum value of 0".55. The published orbit of Wooley and Symms (1937) is shown also.

WDS 08468+0625=ADS 6993=SP AB. All visual and speckle data, covering a baseline of nearly 100 yr, were used to determine a period of 15.05 yr for this pair, identical to that found by Heintz (1963), whose orbit is also plotted. The remaining elements were determined using this period and the speckle data alone. The resulting semimajor axis yields a mass sum 22% larger that that predicted by Heintz.

WDS 09008+4148=Kui 37. The period was determined from all visual and speckle data, the remaining elements from the speckle data alone. The result is a period and eccentricity essentially the same as those found by Heintz (1967), but a semimajor axis about 7% larger and a slightly smaller inclination.

WDS 09123+1459=Fin 347 Aa. A period of 2.703 yr was derived using all data. Speckle data alone [two measurements from 1983.9 by Bonneau *et al.* (1984) were given zero weight] were used to derive the other six elements. The resulting value of a'' is somewhat smaller than that found by either Finsen (1966) or Heintz (1984). The latter published orbit is shown here.

WDS 09474+1134=McA 34. This solution was based on data obtained over nearly one full orbital revolution (all speckle). Although the fit appears very reasonable, we must await several more years' worth of data before the orbit can be declared definitive. Tokovinin (1987a) found a period of 9.70 yr and a much higher eccentricity for this object.

WDS 10427+0335=ADS 7896=A2768. Elements for this object have been gradually refined over the last decade (see Heintz 1978b; Baize 1984; Heintz 1988). Heintz' most recent orbit is shown in the figure. Unfortunately, the first speckle observation of this system occurred in 1978, about 2 yr after periastron.

WDS 13100+1731=ADS 8804=STF 1728. In deriving the orbital elements for this lovely edge-on system, visual and speckle data were used to determine the period, then speckle data alone for the remaining elements. The derived inclination is sufficiently close to 90° that the orbit predicted a partial eclipse ($\Delta m \approx 0.1$ mag, eclipse duration 1.3 days) of one of the F5 V stars by the other in February 1989. Haffner's (1948) orbit is not distinguishable in this figure.

WDS 15318+4053=ADS 9688=A1634 AB. This orbit is based on interferometric measurements only. One data point was obtained by Merrill (1922) in 1921; the other observations were made from 1975 to 1988 and cover about 1.5 revolutions. One unresolved speckle observation was made in 1986.4, at which time the predicted separation was 0".026. Our determination of a'' is about 10% smaller than that of Baize (1985), whose orbit is also plotted here.

WDS 15428+2618=ADS 9757=STF 1967. This is the "oldest" of the binaries in this paper, first observed by F. G. W. Struve in 1826. The first speckle observation was made 150 yr later, in 1976. Thus far speckle data have had little effect on the derived elements; ours are quite similar to those found by Baize (1953).

WDS 17081+3555=ADS 10360=Hu 1176. The orbital period was derived from all visual and speckle data, then the remaining elements were calculated from the speckle data alone, using this period. Coverage by speckle data has been sufficient to resolve the 8 vs 16 yr period ambiguity of some earlier published orbits. The published orbit shown here is by Tokovinin (1984).

WDS 18117+3327=ADS 11149=B 2545. This pair was observed visually five times, from 1958 to 1962, then not again until McAlister observed it with speckle in 1975. Recent quadrant determinations using our speckle data indicate that our observations fall in the same quadrant as the first visual data, the resulting orbit, of period 24 yr, is shown in the upper part of the figure. If the earlier data actually fall in the opposite quadrant (i.e., flipped by 180°), a much longer-period orbit would result. The 58 yr period orbit we derive based on this assumption is also shown in the figure, together with the 47 yr period orbit of Baize (1988). Both our orbits are listed in Table II; the situation will probably remain ambiguous for some time, until the baseline of speckle measurements has increased.

WDS 18384−0312=ADS 11520=A88 AB. The combined visual/speckle orbit was used for the period, then speckle alone was used to derive the remaining elements.

TABLE IV. Orbit residuals.

Star	Orbit Source	Small Visual					Large Visual					CHARA Speckle					Other Speckle				
		N	$\overline{\Delta\theta}$	σ_θ	$\overline{\Delta\rho}$	σ_ρ	N	$\overline{\Delta\theta}$	σ_θ	$\overline{\Delta\rho}$	σ_ρ	N	$\overline{\Delta\theta}$	σ_θ	$\overline{\Delta\rho}$	σ_ρ	N	$\overline{\Delta\theta}$	σ_θ	$\overline{\Delta\rho}$	σ_ρ
ADS 490	CHARA	3	0.7	4.9	-10	42	128	1.2	8.4	-5	38	28	0.0	1.3	1	4	2	-0.5	0.6	-3	5
	Gatewood *et al* (1975)		0.8	4.8	-4	40		2.2	11.3	-1	38		5.3	20.8	18	45		2.1	2.1	-12	13
ADS 1105	CHARA	36	0.5	2.1	4	67	20	-0.4	2.4	7	75	14	-0.7	4.3	-1	6					
ADS 1473	CHARA	11	-0.4	1.6	45	64	52	0.4	4.1	6	53	6	1.3	1.8	-2	4	2	-2.7	2.7	-8	9
Cou 79	CHARA	3	8.4	8.5	25	28	34	-2.3	7.2	12	18	20	0.1	0.8	-2	5	5	-0.6	1.7	-3	6
	Couteau (1987)		4.8	5.1	15	19		-2.5	7.1	6	20		1.0	3.1	-12	14		4.6	10.3	2	18
	Tokovinin (1987b)		7.4	7.5	27	30		-2.6	7.2	14	20		-0.1	1.9	-1	6		-1.4	4.3	2	7
	Tokovinin (1986)		7.3	7.3	9	11		-4.5	12.1	15	24		-3.6	13.6	5	17		-13.1	32.5	9	14
	Baize (1983)		3.4	3.9	12	14		-1.5	7.8	-10	31		4.1	5.0	-30	44		3.7	11.8	-95	110
	Couteau *et al* (1981)		2.9	5.3	22	27		2.8	7.2	-18	31		4.6	8.4	-35	46		8.1	14.7	-92	101
Fin 312	CHARA						189	3.7	11.8	8	15	22	0.0	1.3	0	4	3	-2.0	2.6	-2	8
	Finsen (1970)							-1.4	10.5	11	19		9.9	11.3	3	9		11.2	14.4	-1	15
McA 27	CHARA											18	0.4	2.6	0	4	4	-0.9	1.3	-5	6
	Tokovinin (1986)												0.6	3.6	11	21		-0.4	1.2	4	6
ADS 6185	CHARA	59	-0.7	4.3	27	88	62	-0.3	3.4	-13	97	15	-0.3	1.1	0	4	4	0.7	1.4	-4	5
	Baize (1986)		0.3	4.3	12	90		0.5	3.5	-26	115		-0.2	1.2	5	12		0.4	1.3	8	11
	Tokovinin (1986)		-0.1	4.2	-23	95		-0.1	3.8	-56	129		-3.4	4.0	-7	29		-1.7	2.1	-18	24
ADS 6420	CHARA	33	-0.8	9.7	56	91	130	-1.2	11.3	29	64	9	-0.1	0.9	0	2	3	0.1	0.8	-5	10
	Woolley *et al* (1937)		-0.7	10.1	9	72		-0.8	13.4	-5	63		-3.6	4.0	-29	32		-4.4	4.5	-33	34
ADS 6993	CHARA	21	-2.5	9.7	-3	60	149	0.9	9.4	-8	38	15	-0.1	0.6	1	3	8	-0.2	0.8	-1	3
	Heintz (1963)		-2.1	9.5	11	61		-0.4	8.0	3	38		-2.6	4.5	11	12		-1.0	2.3	9	10
Kui 37	CHARA	60	-1.6	4.5	-7	49	66	0.6	3.3	-15	67	10	0.0	0.2	-1	4					
	Heintz (1967)		-1.1	3.5	13	53		1.1	3.3	-1	61		-1.6	2.1	16	27					
Fin 347	CHARA						49	-1.4	12.6	6	26	12	0.8	1.9	1	2	6	-2.1	4.4	1	6
	Heintz (1984)							-1.5	11.6	5	27		1.8	2.8	-2	5		1.0	2.9	0	6
	Finsen (1966)							2.4	16.4	6	26		34.3	57.5	15	37		-18.4	56.5	-1	16
McA 34	CHARA											18	-0.1	0.8	1	5	3	2.3	3.2	-10	12
	Tokovinin (1987a)												-0.3	1.7	-3	16		-6.6	12.1	-1	7
ADS 7896	CHARA	13	0.5	2.7	22	48	26	-0.1	3.9	-13	51	12	0.0	1.5	4	8	2	-1.9	1.9	15	15
	Heintz (1988)		-0.3	3.0	12	43		-1.2	3.7	-17	55		0.3	1.5	9	12		-1.5	1.6	20	20
	Baize (1984)		-0.7	3.2	33	53		-0.2	3.7	-2	51		3.8	4.1	23	24		2.5	2.5	33	33
	Heintz (1978b)		0.0	3.1	20	45		-2.9	6.0	-10	53		-8.3	8.8	11	16		-10.9	11.0	24	25
ADS 8804	CHARA	205	-1.0	4.4	15	83	205	-0.6	5.5	3	72	30	-0.1	0.8	0	4	3	-0.2	0.4	9	11
	Haffner (1948)		-0.3	4.3	25	85		0.2	5.5	10	71		0.9	1.3	25	28		0.6	0.7	28	29
ADS 9688	CHARA											9	0.1	4.0	0	3	9	0.4	4.7	2	8
	Baize (1985)												-0.1	3.4	-2	7		-6.0	12.0	-1	10
ADS 9757	CHARA	171	0.4	5.8	20	110	153	0.5	3.1	-4	90	31	-0.4	0.7	-1	3	3	-1.2	1.5	7	8
	Baize (1953)		0.2	5.8	4	112		0.4	3.4	-19	95		-1.1	1.3	-46	46		-2.0	2.2	-35	36

TABLE IV. (continued)

Star	Orbit Source	Small Visual					Large Visual					CHARA Speckle					Other Speckle				
		N	$\overline{\Delta\theta}$	σ_θ	$\overline{\Delta\rho}$	σ_ρ	N	$\overline{\Delta\theta}$	σ_θ	$\overline{\Delta\rho}$	σ_ρ	N	$\overline{\Delta\theta}$	σ_θ	$\overline{\Delta\rho}$	σ_ρ	N	$\overline{\Delta\theta}$	σ_θ	$\overline{\Delta\rho}$	σ_ρ
ADS 10360	CHARA						65	-0.8	20.4	24	38	35	-0.2	0.9	0	3	12	1.4	1.9	0	4
	Tokovinin (1984)							2.6	18.7	25	39		0.1	2.9	2	6		2.2	5.3	1	6
	Cester (1964)							0.9	21.0	14	34		-2.6	9.1	-7	14		-1.5	10.9	-11	16
	Wilson (1936)							0.4	28.8	4	37		-1.9	26.5	-37	44		3.2	25.9	-22	37
ADS 11149	CHARA orbit #1						10	2.9	5.4	16	22	33	0.1	1.5	0	4	7	0.5	3.0	0	5
	CHARA orbit #2							2.9	5.3	10	20		0.2	1.5	0	4		0.5	3.0	-1	4
	Baize (1938)							2.5	5.3	14	19		-1.0	1.8	-6	9		-0.7	3.6	-6	8
ADS 11520	CHARA	1	8.5	—	65	—	87	1.8	12.1	21	30	16	0.1	1.3	0	5	3	-1.8	2.5	7	7
	Heintz (1988)		6.6	—	46	—		1.3	11.2	4	25		-2.4	3.2	-18	21		-2.7	4.5	-18	18
	van den Bos (1953)		4.8	—	27	—		-0.5	11.1	-11	31		-6.4	7.2	-37	38		-5.4	6.2	-35	36
ADS 12973	CHARA	10	-0.8	6.8	47	77	142	-0.2	5.6	20	40	22	0.7	2.1	1	3	3	0.9	1.7	-3	4
	Heintz (1984)		-0.5	6.7	26	67		0.0	5.6	-1	36		0.0	2.5	-11	13		1.6	2.2	-17	18
	Tokovinin (1984)		-1.9	7.3	59	84		-1.5	5.9	30	46		-2.0	5.9	8	10		-3.0	3.4	9	11
	Finsen (1937)		0.3	6.2	21	63		1.0	7.4	-4	37		17.6	29.0	-38	48		12.7	16.1	-53	54
ADS 14073	CHARA	139	2.7	6.2	35	75	263	4.0	7.3	21	65	23	0.0	0.6	0	3	7	-0.9	1.3	3	6
	Couteau (1962)		-0.1	4.1	4	68		-0.4	4.3	-6	60		-0.4	1.5	-33	35		-1.5	2.3	-20	24
	Finsen (1938)		-1.0	4.4	-4	69		-1.7	4.6	-16	62		-2.6	3.5	-30	33		-5.6	6.9	-20	25
ADS 14121	CHARA						2	16.0	16.6	-40	45	26	-0.3	1.0	1	4	8	-4.5	13.5	10	30
ADS 14412	CHARA	1	8.9	—	36	—	38	1.2	8.4	6	26	20	0.0	1.6	0	4	1	-3.2	—	8	—
	Heintz (1986b)		7.3	—	32	—		1.3	7.7	3	27		-0.7	2.3	-1	5		-4.4	—	9	—
	Ling (1[illegible])		7.1	—	33	—		1.2	8.6	4	26		-1.1	2.3	-2	5		-4.8	—	7	—
	Starikova (1983)		7.0	—	27	—		2.1	8.1	-6	32		4.4	5.7	-8	12		2.3	—	5	—
	Eggen (1965)		10.2	—	52	—		5.2	10.8	13	34		12.5	12.9	-3	9		8.4	—	12	—
	Heintz (1956)		7.9	—	-3	—		-3.1	9.3	-16	35		-21.9	22.7	-7	10		-25.2	—	5	—
ADS 14761	CHARA	6	-0.3	7.0	1	5	91	-0.2	11.8	14	43	22	0.1	1.8	-2	4	2	-1.7	2.3	1	1
	Baize (1961)		1.6	7.1	-17	18		0.0	15.6	4	45		2.8	3.2	-12	12		1.3	1.4	-8	8
Kui 108	CHARA	5	-5.4	9.5	-10	19	46	0.6	6.9	7	28	25	-0.2	0.9	-1	3	6	-0.8	1.4	0	5
	Heintz (1986a)		-3.4	8.9	-3	14		3.0	6.4	8	29		-2.3	2.7	-3	5		-3.1	3.3	-4	6
	Baize (1985)		-3.4	8.4	-5	16		2.8	6.9	9	29		0.9	1.6	0	3		0.5	1.2	-1	5
	Morel (1970)		-1.7	9.4	-15	21		2.2	6.8	-3	27		-8.7	9.3	-8	9		-7.1	7.3	-8	9
ADS 15281	CHARA	30	5.1	14.1	12	48	204	1.4	11.7	8	43	36	0.1	1.6	0	3	7	-1.3	2.6	1	6
	Tokovinin (1984)		2.8	12.5	16	50		-3.0	13.5	12	46		0.2	2.6	3	5		-1.3	3.6	5	8
	Morel *et al* (1972)		3.2	14.6	-5	50		-2.4	12.1	-8	46		3.2	8.2	-12	15		0.7	1.8	-19	22
Cou 14	CHARA	7	-2.2	4.5	23	29	81	0.0	4.2	9	37	22	-0.1	0.7	-2	4	5	0.6	2.0	-2	4
	Baize (1986)		-3.0	4.3	-19	25		0.6	4.5	-33	52		0.5	3.6	-54	69		1.0	1.7	-59	63
	Docobo *et al* (1985)		-4.6	5.7	15	20		-0.5	3.9	1	35		0.9	2.4	-18	33		1.1	2.0	-16	19
	Heintz (1982)		-3.9	5.0	14	21		1.4	4.6	3	35		5.2	6.3	-22	46		6.1	6.3	-14	18
ADS 16173	CHARA	47	-0.1	3.5	0	36	133	0.2	4.4	-13	54	15	0.2	1.1	1	3	7	-2.5	3.1	0	3
	Heintz (1986a)		0.3	3.4	3	36		0.6	4.4	-9	53		-0.4	2.1	5	6		-8.4	9.6	3	7
	Baize (1957)		0.3	3.5	4	38		0.6	5.4	-8	55		-4.3	10.2	11	17		-32.5	37.8	7	24

The resulting orbit is signficantly smaller than the published orbits of van den Bos (1953) and Heintz (1988—plotted here).

WDS 19489+1908=ADS 12973=AGC 11. Visual and speckle data were used to derive the period, then the speckle data were used alone to derive the other six elements. Visual data covering an additional two full revolutions, plus a good collection of speckle data, have allowed refinement of Finsen's (1937) grade 1 orbit. Our elements are similar to those recently published by Tokovinin (1984), whose orbit is also shown here. We each derive a value for *a"*—and thus a sum of masses—considerably smaller than that found by either Finsen or Heintz (1984).

WDS 20375+1436=ADS 14073=Bu 151. This system was discovered in 1874 and first observed by speckle in 1973. This is yet another speckle orbit using a period defined by all the data. Couteau's (1962) orbit is shown in the lower right-hand corner of the figure, together with our new orbit and all published speckle data.

WDS 20397+1556=ADS 14121=WCK Aa. The two visual observations of this pair were given zero weight in the orbit program, as were two measurements made in 1983 and 1984 by Tokovinin (1985).

WDS 20538+5919=ADS 14412=A751. Three published orbits have appeared for this pair in the last few years (see Starikova 1983; Ling 1985; and Heintz 1986b—shown in the figure); here now is a fourth.

WDS 21135+1559=ADS 14761=Hu 767. The speckle data refine Baize's (1961) elements, although unfortunately speckle observations did not begin until shortly after periastron and the first speckle data point appears discrepant.

WDS 21425+4106=Kui 108. The orbits of Heintz (1986a) and Baize (1985), as well as this one, indicate that *a"* is about 6% smaller than was found by Morel (1970). Our orbit is slightly more eccentric than those of Heintz and Baize, and we find a somewhat earlier time of periastron passage. Heintz' orbit is plotted here.

WDS 21446+2539=ADS 15281=Bu 989. The period was determined by a combined visual/speckle orbit, then the other elements were derived using speckle data alone. The top portion of the figure shows all visual and speckle observations for this binary, the bottom portion only the speckle data. The dotted orbit in both cases is derived from the elements of Tokovinin (1984).

WDS 21502+1718=Cou 14. The visual/speckle orbit of this system has a shorter period and a considerably smaller semimajor axis than any published in the last several years (see Heintz 1982, Docobo and Costa 1985; Baize 1986). Baize's orbit is shown here.

WDS 22408+1432=ADS 16173=Ho 296. The combined visual/speckle orbit yielded the period, used with the speckle data alone to generate the other elements. The resulting orbit is quite similar to that of Baize (1957) and essentially the same as that of Heintz (1986a), which is plotted here.

We are grateful for the assistance of Charles Worley in obtaining visual data for these binaries from the *Washington Visual Double Star Catalog*, maintained by Worley at the U.S. Naval Observatory. This service is invaluable to all computers of visual orbital elements. We also thank Wayne Warren and the staff of the Astronomical Data Center at the NASA Goddard Space Flight Center for providing us with magnetic tape versions of the WDS and other useful catalogs. Finally, we thank the many observers at CHARA and elsewhere who have assisted in collecting the large body of speckle data now available for orbit determination.

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BINARY STAR ORBITS FROM SPECKLE INTERFEROMETRY. III. THE EVOLUTION OF THE CAPELLA STARS

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ABSTRACT

A new orbit for Capella has been computed, incorporating the latest available speckle-interferometry data. This, combined with van Altena's (1988) parallax data, gives a total mass of $4.58\mathscr{M}_\odot \pm 9\%$ for the two components. The comparatively low mass found is more consistent with the "convective overshoot" models of Bertelli *et al.* (1986). The Strömgren y, b, and v magnitude differences of the Capella binary were estimated by Bagnuolo and Sowell (1988), and these data were converted into the spectral types and temperatures of the two stars. These results, when compared to various stellar evolutionary tracks, tend to support the belief that the "G star" (Capella *Aa*) is at the beginning of the red giant branch (RGB), not at the core-helium-burning (CHB) phase in its evolution. Other available data for or against the RGB hypothesis are discussed.

I. INTRODUCTION

In addition to determining accurate orbits, a goal of the GSU/CHARA program of binary star speckle interferometry has been to develop methods of determining the magnitudes and colors of the individual components of binary stars with angular separations down to the diffraction limit. The "Fork" algorithm (Bagnuolo 1988a) has provided a new, direct means of measuring the luminosities and temperatures of the well-known spectroscopic binary, Capella.

Capella (α Aur, HR 1708) was independently recognized to be a spectroscopic double by Campbell (1899) and Newall (1899). Classification of stars with composite spectra is notoriously difficult, however (Bidelman 1984), especially if, as in the case of Capella, Δm is small. Estimation of these stars' magnitude difference and mass ratio, as well as $v \sin i$ of the *Ab* component, has also been difficult, due to the combination of broad lines in *Ab* and numerous lines in the late spectral type primary *Aa* (Fekel *et al.* 1986). A spectrophotometric analysis by Wright (1954) appeared to settle the issue: the spectroscopic primary (Capella *Aa*, larger mass) was approximately of type G5 III and brighter than the G0 III secondary by about 0.25 mag at 550 nm. Recently, however, Griffin and Griffin (1986) reversed Wright's assignment of relative magnitudes based on their integrated radial-velocity profiles. Our data confirm the Griffins' result and indicate that the secondary is brighter by 0.09, 0.23, and 0.55 mag in Strömgren y, b, and v, respectively. From this, the spectral types have been estimated to be G0 III and G9 III. Similar results have been found in a recent spectrophotometric analysis by Strassmeier and Fekel (1990).

In this paper we first consider a revised orbit for Capella, based upon the latest available speckle data, and estimate the masses of the stars. We then discuss these data together with the individual star photometry and their implications for the evolutionary state of the Capella stars.

II. MASSES AND ABSOLUTE MAGNITUDES

McAlister (1981) derived an apparent orbit for Capella based on 56 interferometric observations, including both modern speckle data and visual Michelson interferometric measurements obtained at Mount Wilson by Anderson (1920) and Merrill (1922). This system has remained a popular target for interferometric observation since the time of McAlister's analysis; the number of measurements listed in the *Second Catalog of Interferometric Measurements of Binary Stars* (McAlister and Hartkopf 1988) now totals over 100.

We have calculated a new apparent orbit for Capella, including data through 1988, using the "grid search" method described by McAlister *et al.* (1988) and Hartkopf *et al.* (1989). The resulting orbital elements are shown in Table I, together with the earlier results of McAlister. Differences between the two orbits are minor. The semimajor axis increased by 0.5 mas, or less than 1%, while the period decreased by about 25 s, or 1 part in 360 000. (This excellent agreement in period is due in large measure to the excellent data of Anderson and Merrill, which give us a time span of some 240 full revolutions.) The overall effect of these new elements is an increase in the derived mass sum of approximately 2.9% at a given parallax.

We have in addition obtained parallax data generously provided by Van Altena (1988), based on trigonometric parallax measurements produced by seven observatories. Measurements of $0\farcs0780 \pm 0\farcs0042$ for Capella A and $0\farcs0763 \pm 0\farcs0028$ for the fainter and better determined Capella H combine to give a weighted parallax of $0\farcs0768 \pm 0\farcs0023$ for this system. The total mass of Capella is consequently $\mathscr{M}_{\rm sum} = 4.58 \pm 0.41\ \mathscr{M}_\odot$ or about $2.29 \pm 0.20\ \mathscr{M}_\odot$, each using a mass ratio of 1. For a mass

TABLE I. Orbital elements for Capella.

	McAlister (1981)	This paper
P	$104\fd0237 + 0\fd0002$	$104\fd0234 \pm 0\fd0017$
a	$0\farcs0547 \pm 0\farcs0001$	$0\farcs05523 \pm 0\farcs00008$
i	$136\fdg64 \pm 0\fdg10$	$136\fdg63 \pm 0\fdg48$
Ω	$220\fdg22 \pm 0\fdg15$	$221\fdg21 \pm 1\fdg52$
T	1936.4581 ± 0.0001	1936.5045 ± 0.0008
e	0.0 (adopted)	0.005 ± 0.008
ω	$0\fdg0$ (adopted)	$59\fdg44 \pm 1\fdg52$

Notes to TABLE I. In the earlier set of orbital elements, the value of ω was increased by 180° to reflect the quadrant determinations of Bagnuolo and McAlister (1983). Also, our method of error determination is apparently rather more conservative than that used by McAlister. A derivation of elements using our program with McAlister's data yielded errors very similar to those quoted for the new set of elements.

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ratio of 1.05 (Wright 1954) the stars have masses of 2.35 and 2.24 $\mathcal{M}_{\odot}$, respectively. For comparison, Batten *et al.* (1978) give masses of 2.67 and 2.55 $\mathcal{M}_{\odot}$ for the components, based on values of $K_1 = 26.1$ km/s and $K_2 = 27.5$ km/s (Batten and Erceg 1975; Wright 1954) and $i = 137\overset{\circ}{.}05$ (Finsen 1975). With our value for the inclination of $136\overset{\circ}{.}63$ their masses reduce to 2.61 and 2.49 $\mathcal{M}_{\odot}$.

In view of the uncertainties in radial-velocity determinations, especially for the secondary (see Sec. IV), this 10% difference in estimated mass between the two methods is probably not significant. We also believe that the trigonometric parallax method is more reliable at present.

III. THE EVOLUTIONARY STATE OF THE CAPELLA STARS

The Capella stars are a rare example of two evolved giants, and their properties have been an important test for theoretical models of stellar evolution. The Wright data led to the interpretation by Iben (1965) that the G star had passed the red giant branch (RGB) phase and was in the core-helium-burning (CHB) phase. Iben further noted that these data were compatible with Wallerstein's (1964) estimate that the lithium abundance ratio of the F and G stars was Li(F)/Li(G) ≈ 100.

However, Boesgaard (1971) detected lithium in the G star and revised this ratio to about 15, which would be more compatible with the G star on the RGB. She states that the Li ratio would be 48:1 if the G star had reached even as far as point 11 on Iben's evolutionary track (i.e., about halfway up the RGB); therefore, the actual position of the star should be considerably earlier than this. There was therefore a conflict between the estimated lithium abundance, supporting the RGB interpretation, and the estimated temperatures and colors of the stars, which support the CHB model.

Our temperatures and absolute bolometric magnitudes, based on the temperature scale and B.C.'s of Kurucz (1988) and Bell and Gustafsson (1978), are as follows: for the G star (spectral type G9 III), $T_e = 4800$ K and $\mathcal{M}_{\rm bol} =$ [illegible], while for the F star (spectral type G0 III), $T_e = 5500$ K [illegible] $\mathcal{M}_{\rm bol} = 0.14$. We have used Van Altena's trigonometric parallax to convert to absolute magnitudes, and have assumed the $\mathcal{M}_{\rm bol}$ of the Sun to be 4.76.

These data can be compared with various theoretical evolutionary tracks. Five evolutionary tracks were chosen, each for stars having "solar" abundances (although the values chosen for solar abundance differ slightly—see Table II). Andersen *et al.* (1988) have shown the effects of varying Y and Z in fitting the stars of the eclipsing binary AI Phoenicis, whose masses were determined to be 1.24 and 1.20 $\mathcal{M}_{\odot}$. Fits of $(Y,Z) = (0.312, 0.0169)$ and $(0.250, 0.0100)$ were essentially equivalent, which suggests that VandenBerg's (1985) model should be comparable to the other three recent models we considered. See also Popper *et al.* (1986) for a similar discussion.

Two particular points of interest in these evolutionary tracks are their overall luminosities (e.g., models with convective overshooting tend to be brighter for a given mass) and the difference in luminosity between a G0 star at $\log T_e = 3.75$ and the bottom of the CHB phase. This difference in $\log L$ is referred to henceforth as $\Delta L_{\rm CHB}$. Models with a large $\Delta L_{\rm CHB}$ can only explain the small observed luminosity difference between the G and F stars via the RGB hypothesis.

Figure 1 is a plot of the Capella data with Iben's (1965) evolutionary tracks for a 3.0 $\mathcal{M}_{\odot}$ star of solar abundance. Due to improvements in opacity estimates, model atmosphere codes, and computers, this result is largely of historic interest, as it was perhaps the first set of calculations to show the basic "topology" of stellar evolution in this mass range. Using Wright's data, Iben concluded that the CHB interpretation was correct. Our data have also been replotted with old calibrations of temperature and B.C. for comparison

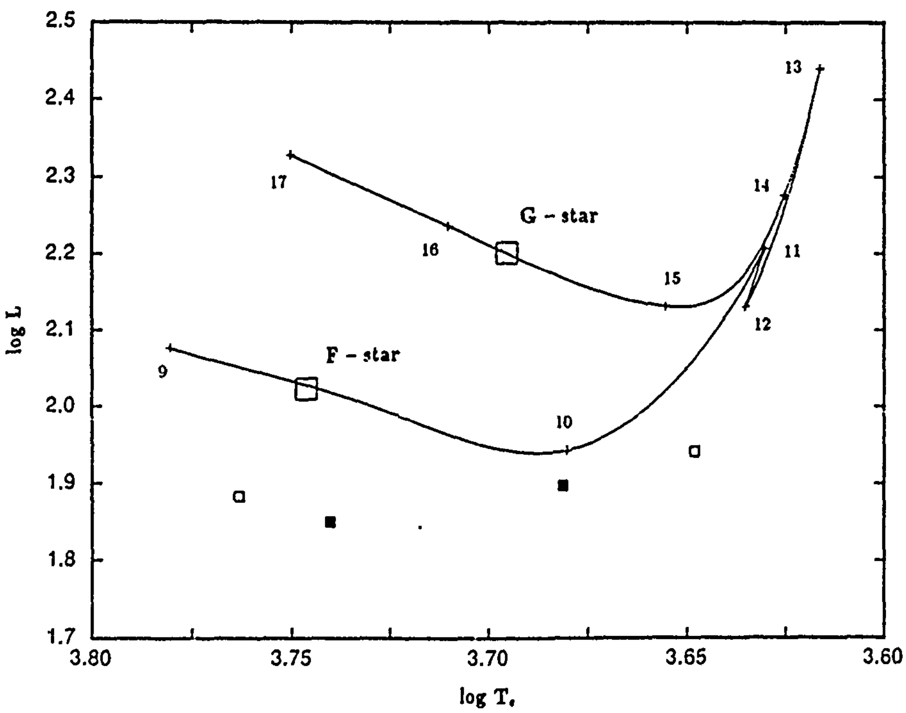

FIG. 1. Comparison of Capella star H-R diagram positions with Iben's 3.0 $\mathcal{M}_{\odot}$ evolutionary track. The solid line and numbers represent evolutionary tracks, the large open squares positions of the G and F stars according to Iben's interpretation of Wright's (1954) data. The small filled squares indicate the positions of the stars according to Bagnuolo and Sowell (1988), while the small open squares indicate the same data with the old temperature and B.C. calibration.

(Allen 1973). The difference in log L between the two stars is about 0.05, while $\Delta L_{\rm CHB}$ for this model is about 0.10. Therefore, the relative location of the stars in (log T_e, log L) favors the RGB hypothesis.

Figures 2 and 3 compare the Capella data to the more recent evolutionary tracks of VandenBerg (1985) and Bertelli *et al.* (1986), respectively. The values of $\Delta L_{\rm CHB}$ in Fig. 3 (and from the tabulated results) are 0.151 and 0.129 for 2 and 3 $\mathscr{M}_\odot$ stars, respectively. Thus, the CHB hypothesis is an even poorer fit to the data for these theoretical models.

Table II compares the three stellar evolutionary tracks previously discussed with two others by Maeder and Meynet (1988) and Dearborn (1989). Both the latter models assume some convective overshooting, but differ in assumed opacities. The fourth column of Table II lists the luminosity at log $T_e = 3.75$. Note that $\Delta L_{\rm CHB}$ is less than zero for the Maeder and Meynet models; thus, both RGB and CHB are compatible with the data for this model.

The color–magnitude data on the whole are more compatible with the RGB than CHB interpretation, but clearly the result is model dependent.

If the RGB interpretation is true, then the mass difference of the stars must be small, as was noted by Ayres *et al.* (1983). For example, the F and G stars are approximately at points "9.5" and "10.3" on Iben's track (Fig. 1), which correspond to a time difference of about $\Delta t \approx 7.1 \times 10^6$ yr, or $\Delta t / t_{\rm ms} \approx 3.2 \times 10^{-3}$, where $t_{\rm ms}$ is the main-sequence lifetime.

According to Iben (1988), $t_{\rm ms} \propto m^{-2.2}$ or $\Delta t / t_{\rm ms} = -2.2\,\Delta m/m$. In other words, $\Delta m/m = -0.455\,\Delta t/t_{\rm ms} = 0.00145$. Thus, this time difference corresponds to a mass difference of only $0.004\mathscr{M}_\odot$. Of course, this analysis assumes coevality and no differential mass loss. However, the analysis suggests the possibility that the stars may be even "more equal" in mass than previously measured. Recent estimates of the mass ratio have ranged from 1.18 (Shen *et al.* 1985) to Wright's value of 1.05, and will be discussed later.

The change in luminosity of the two stellar evolutionary tracks can also be estimated. Because $L \propto m^{3.2}$, $\Delta \log L = -3.2\,\Delta \log m = 0.0046$. This is only about 1/9 of the observed difference in luminosity, so that the two stars are racing along almost the same track, assuming the RGB interpretation.

The stellar evolutionary models can also be compared with the estimated luminosities of the stars. The tracks by Iben (1965), VandenBerg (1965), Bertelli *et al.* (1986), Maeder and Meynet (1988), and Dearborn (1989) are consistent with average masses for the Capella stars of about 2.67, 2.83, 2.37, 2.65, and 2.80 $\mathscr{M}_\odot$, respectively. The Bertelli *et al.* model therefore appears to be most consistent with the 2.3$\mathscr{M}_\odot$ masses found in Sec. II. Thus, although Andersen *et al.* found than VandenBerg's models without convective overshooting fit the $\sim 1.2\mathscr{M}_\odot$ stars of AI Phe, perhaps convective overshooting does occur for more massive stars like Capella.

IV. OTHER DATA

Other relevant data are the ultraviolet luminosity and the observed mass ratios. According to Ayres *et al.* (1983), the enhanced UV emission of the Capella giants compared to other yellow giants in IUE low-dispersion surveys supports the RGB hypothesis. If the G star had evolved to the CHB stage, most of the observed strong chromospheric and coronal emission would have been lost.

The observed mass ratios are contradictory. Shen *et al.* (1985) have determined a mass ratio of the components of $\mathscr{M}_G/\mathscr{M}_F = 1.18$ via spectroscopy. However, the previous result by Wright was a ratio of 1.05. As we have seen, stars

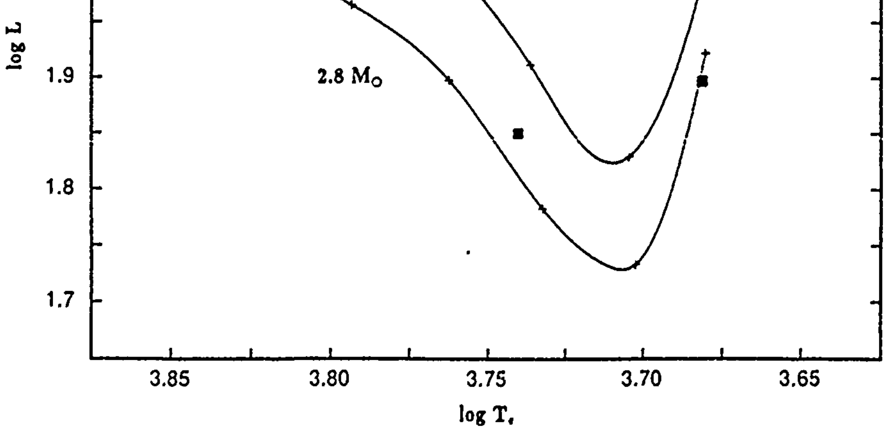

FIG. 2. Comparison of Capella data to the evolutionary tracks of VandenBerg (1985).

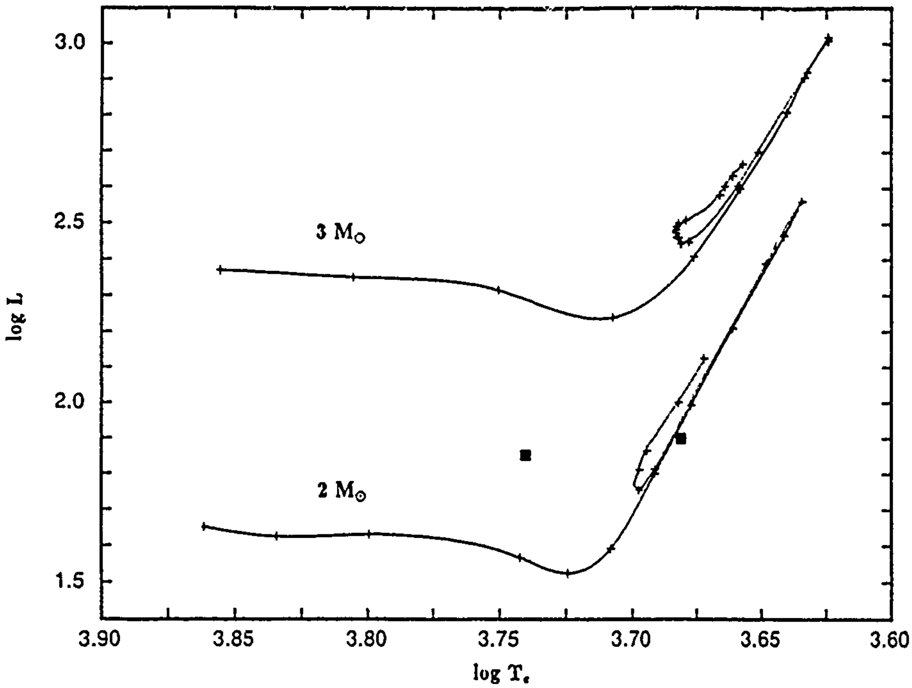

FIG. 3. Comparison of Capella data to the evolutionary tracks of Bertelli *et al.* (1986).

with a high mass ratio cannot both be on or near the RGB; the more massive must have evolved to the CHB stage. Thus, the Shen *et al.* data support the CHB interpretation (although with *this* large a mass difference the more massive star would probably have evolved beyond the CHB phase).

Because the Shen *et al.* data provide the only major inconsistency (i.e., clearly support the CHB hypothesis), their results must be especially scrutinized. (Admittedly, this is *ex post* logic.) Their mass ratio depends upon their observations of the broadened lines of the F star, Capella *Ab*, to which they have added at almost equal weight some 1939 measurements by W. Struve. We feel their data may be biased toward too high a value of the radial-velocity amplitude for this star K_2 by the following effects:

(1) Shen *et al.*'s Fig. 1 shows a profile for the 0.749 phase which is dominated by the primary and is therefore almost an instrumental profile. Note that the continuum is fairly smooth to the left, but has large features to the right. This suggests that their results near 0.5 phase will be more accurate than those near 0.0 phase. Furthermore, the shape of these features suggests that there will be a bias toward higher radial velocities measured at close to 0.0 phase. In their Fig. 3, there is good agreement between their radial velocities for Capella *Ab* and those of Struve near the 0.0 phase; at 0.5 phase the latter are systematically higher. One may tentatively conclude that Shen *et al.*'s R.V.'s are good near 0.5 phase, but too high near 0.0 phase, while the Struve data are uniformly too high. Thus, K_2 and the mass ratio have quite possibly been overestimated.

(2) Shen *et al.*'s Figs. 1 and 2 show fitted Gaussians of different widths to the primary and secondary "dips" produced from the cross correlation of the spectrum with a mask spectrum of a similar star. However, the continuum is not well fitted by their models. Griffin (1988) noted this effect and has suggested that the radial-velocity difference between the two components is considerably less than the 27.5 km/s found by Shen *et al.* for the 0.672 phase observation shown in the top portion of their Fig. 2. (See also their Table III, which gives radial velocities of 15.6 and 43.1 km/s for *Aa* and *Ab*, respectively.) Again, K_2 may have been overestimated.

(3) The shape of the secondary dip shows superimposed features that change with phase. Griffin's (1982) data, taken with a larger aperture, show a smooth dip with no such features. The latter result suggests that the features in the secondary dip in Shen *et al.*'s data are mainly instrumental, and their variation with phase represents systematic instrumental errors.

To conclude, we feel that the radial-velocity question is still open and that a credible mass ratio by this method is yet to be determined. We do not wish to denigrate the great efforts of Shen *et al.* or earlier observers to resolve this difficult problem. One of us has recently proposed (Bagnuolo 1988b) using a method of pupil plane interferometry to obtain the spectra of stars like Capella separately, but it is likely that existing techniques can determine a more accurate mass ratio. Recently, preliminary radial-velocity measurements by Stassmeier and Fekel (1990) indicate that the mass difference may be quite small between the components.

TABLE II. Comparison of stellar evolution models.

Author	$\mathcal{M}/\mathcal{M}_\odot$	(Y,Z)	$L_{3.75}$	ΔL_{CHB}
Iben (1965)	3.0	0.272, 0.02	2.04	0.10
VandenBerg (1985)	3.0	0.25, 0.0169	1.97	—
	2.8		1.85	—
Bertelli *et al.* (1980)	3.0	0.28, 0.02	2.32	0.151
	2.0		1.58	0.129
Maeder and Meynet (1988)	3.0	0.28, 0.02	2.10	−0.007
	2.5		1.79	−0.019
Dearborn (1989)	2.5	0.28, 0.02	1.69	0.070

V. CONCLUSIONS

The available evidence tends to favor the red giant branch (RGB) over the core-helium-burning (CHB) hypothesis for the Capella stars. Additional observations are needed to accurately determine both the mass ratios of the components and the lithium abundance of the secondary to settle any remaining inconsistencies. The latter has not been redetermined in 18 yr and could clearly benefit from modern observational techniques.

Combining the best available orbital and parallax data leads to absolute luminosities and masses that are most consistent with the models of Bertelli *et al.* (1986).

The authors would like to thank Icko Iben, Ingemar Furenlid, and Hal McAlister for several interesting discussions relating to this topic. Doug Gies, Jim Sowell, and Tom Meylan also provided useful criticism. The GSU/CHARA program of binary star speckle interferometry is supported by the National Science Foundation through NSF Grant No. AST 8613095 and the Air Force Office of Scientific Research through AFOSR Grant No. 860134. We gratefully acknowledge this support.

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ICCD SPECKLE OBSERVATIONS OF BINARY STARS. V. MEASUREMENTS DURING 1988–1989 FROM THE KITT PEAK AND THE CERRO TOLOLO 4-m TELESCOPES

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ABSTRACT

One thousand one hundred and fifty eight measurements of 1,056 binary star systems observed mainly during 1988 and 1989 by means of speckle interferometry with the 4–m telescopes on Kitt Peak and Cerro Tòlolo are presented. Eight systems are resolved for the first time. This program, begun at Kitt Peak in 1975, has now been expanded to include the southern hemisphere.

I. INTRODUCTION

This paper is a report of the continuing effort to provide high accuracy, high angular resolution measurements of binary star systems by speckle methods. After nearly 14 years of continuous activity in the northern hemisphere, this program has now been expanded to the southern sky. We here present measurements from the 4–m telescopes on Kitt Peak, obtained during August, 1988 and March, 1989, and Cerro Tololo, obtained in April, 1989. The CTIO results are the largest sample of speckle observations of binary stars yet to come from the southern hemisphere, and we hope to be able to continue routine observations over the entire sky. As demonstrated by the first results of extensive orbit calculations from observational material accumulated in this program (Hartkopf *et al.* 1989), it is through a continuing, long–term observing program that speckle interferometry will substantially contribute to binary star studies.

II. NEW MEASUREMENTS

The instrumentation and data acquisition and analysis procedures are identical to those described in Paper IV (McAlister *et al.* 1989) of this series. Calibration measurements using a double–slit pupil mask were obtained for the Kitt Peak observations. The Cerro Tololo results were tied into the Kitt Peak "system" by observing binaries near the celestial equator from both locations that would show no measurable orbital motions during the month separating the spring 1989 observing runs.

The GSU speckle camera was scheduled for 10 nights during the two KPNO runs and for four nights at CTIO. Altogether 1139 series of observations were obtained on Kitt Peak while perfect weather in Chile permitted us to collect an additional 775 data series from the southern hemisphere. These data were reduced in Atlanta to yield a total of 1,158 measurements of 1,056 binary star systems.

Table I contains observational and catalog information for the eight new systems

presented in this paper. Six of the newly resolved pairs were discovered as close companions to wider visual binaries, thus representing six new triple systems. These are designated as such in the last column of Table I. We have tentatively designated new components in previously known binary systems as Aa even though the autocorrelation analysis does not establish whether the additional star is associated with component A or B. We are now working toward eliminating these ambiguities, as well as the 180° quadrant ambiguity inherent in autocorrelation methods, using other techniques. Those results will be published separately, but examples of these *speckle photometry* techniques, as applied in studies of the binaries Finsen 342 and Capella, can be found in McAlister *et al* (1988) and Bagnuolo and Sowell (1988), respectively.

One of the new stars in Table I, CHARA 146 = HR 6027 = ν Sco, is a member of the Sco–Cen association. The remaining two newly resolved stars were observed due to their known or suspected radial velocity variations, indicated by "SB" in Table I, but are also third components in known systems. CHARA 145 = HD 86590 = DH Leo is a third companion in a short–period spectroscopic binary whose observational history is summarized by Barden (1984). From his spectroscopic observations, Barden was able to detect three stars of K spectral type of which the RS CVn nature of the system arises from the secondary component in the 1.07–day system. The third component was detected in the spectrum by Barden and has subsequently been observed by Fekel (private communication, 1989) who finds no velocity change in excess of ± 2 km/sec from 12 spectra obtained since 1984.0. It seems very likely that we have detected this third component in HD 86590. CHARA 148 = HD 167954 is a single–lined spectroscopic binary with a period of 120 days (Bopp *et al.* 1970). With the observed angular separation of 0.31 arcsec, the component we report here is probably not the known spectroscopic system.

We continue our practice of assigning "CHARA numbers" to these systems, and the total number of "McA" and "CHARA" stars is now 224. Many of these systems show very rapid orbital motion, and, if they were not already known as spectroscopic binaries, are prime candidates for radial velocity observations. As examples of rapid motion, we show in Figure 1 the collected speckle observations of four CHARA stars, all of which were discovered after 1984.0. Twelve previously discovered CHARA stars have been confirmed here: #12 (HD 23489); #41 (HR 5323); #58 (HR 6286); #60 (HD 155328); #77 (HR 7053); #88 (HR 7480); #111 (HR 8581); #121 (HR 9097); #122 (HD 225218); #132 (HD 91172); and, #133 (HR 4380). Several of these systems have also shown significant orbital motions since their discoveries. For example, CHARA 60 and 88 haved moved through 73° and 61°, respectively, in the 3.8 yr since their first resolution. CHARA 77, a

newly discovered companion to ϵ Lyrae C, moved through 36° and closed from 0.18 to 0.04 arcsec since its first resolution on 1985.518. Finally, reexamination of an autocorrelogram obtained in November 1986 at the KPNO 4-meter has provided us with a "prediscovery" confirmation of CHARA 149 (this observation is included in Table II).

The new measurements of binary stars are presented in Table II, where we condense the format used in Paper IV. The coordinates in Table II, which also serve as the *Washington Double Star Catalog* (WDS) number, are for equinox 2000.0, but the position angles have not been corrected for precession and are thus based upon the equinox for the epoch of observation shown as the fraction of the Besselian year. The measured angular separations in this sample range from a minimum value of 0.021 arcsec for the newly discovered third component in the visual binary HDO 207 = HD 79699 to 2.857 arcsec for the visual companion to α Sco. The median separation here is 0.238 arcsec compared with the mean separation of 0.35 arcsec for the nearly 9,000 interferometric measurements compiled in the catalog of McAlister and Hartkopf (1988). The lower limit in the observed separation range is significantly below the Rayleigh limit for the 4–m telescope, but, as is seen in Figure 2, the vector–autocorrelogram for HD 79699 clearly shows doubling of the characteristic peak. The detection of triple systems such as this one is an application (indeed about the only practical application) of "speckle holography" (*cf* Weigelt 1983), in which the wide component acts as a reference point source for the deconvolution of the close pair.

Southern declinations have been virtually ignored in any systematic application of binary star speckle interferometry. The 334 measures of systems with $\delta \leq$ -30° in Table II represent a tenfold increase for this declination zone from the number of measurements listed in the catalog of McAlister and Hartkopf (1988). Many of the objects we observed have not been inspected by either visual or interferometric methods for several decades. It is our goal to continue uniform speckle coverage in both hemispheres.

As in all previous papers, we are indebted to the efforts of the telescope operators in maintaining the highest observing efficiency. We thank Dean Hudek, Hal Halbedel, and Don Martin for their cheerful and dedicated cooperation on Kitt Peak. Our first experience on Cerro Tololo was all the more pleasing due to the gracious treatment we received by every CTIO staff member. We particularly relied on Oscar Saa for his kind logistical support and on Hernan Tirado for his expert job in operating the 4–m telescope. Clark Enterline, of the CTIO liason office in Tucson, provided valuable assistance in shipping

our equipment overseas. Graduate student Don Barry assisted with the August observing run. We thank Charles Worley for again commenting on our results in advance of publication. Frank Fekel kindly provided us information about HD 86590 after alerting us to its suitability for speckle observation. Research in speckle interferometry at Georgia State University is supported by the GSU College of Arts and Sciences and the Office of the Vice President for Research. The National Science Foundation (AST 86-13095) and the Air Force Office of Scientific Research (AFOSR 86-0134) provided support for this effort through grants to GSU. O.G.F. acknowledges the partial support of the Space Telescope Science Institute (STScI Grant CW-0005-85).

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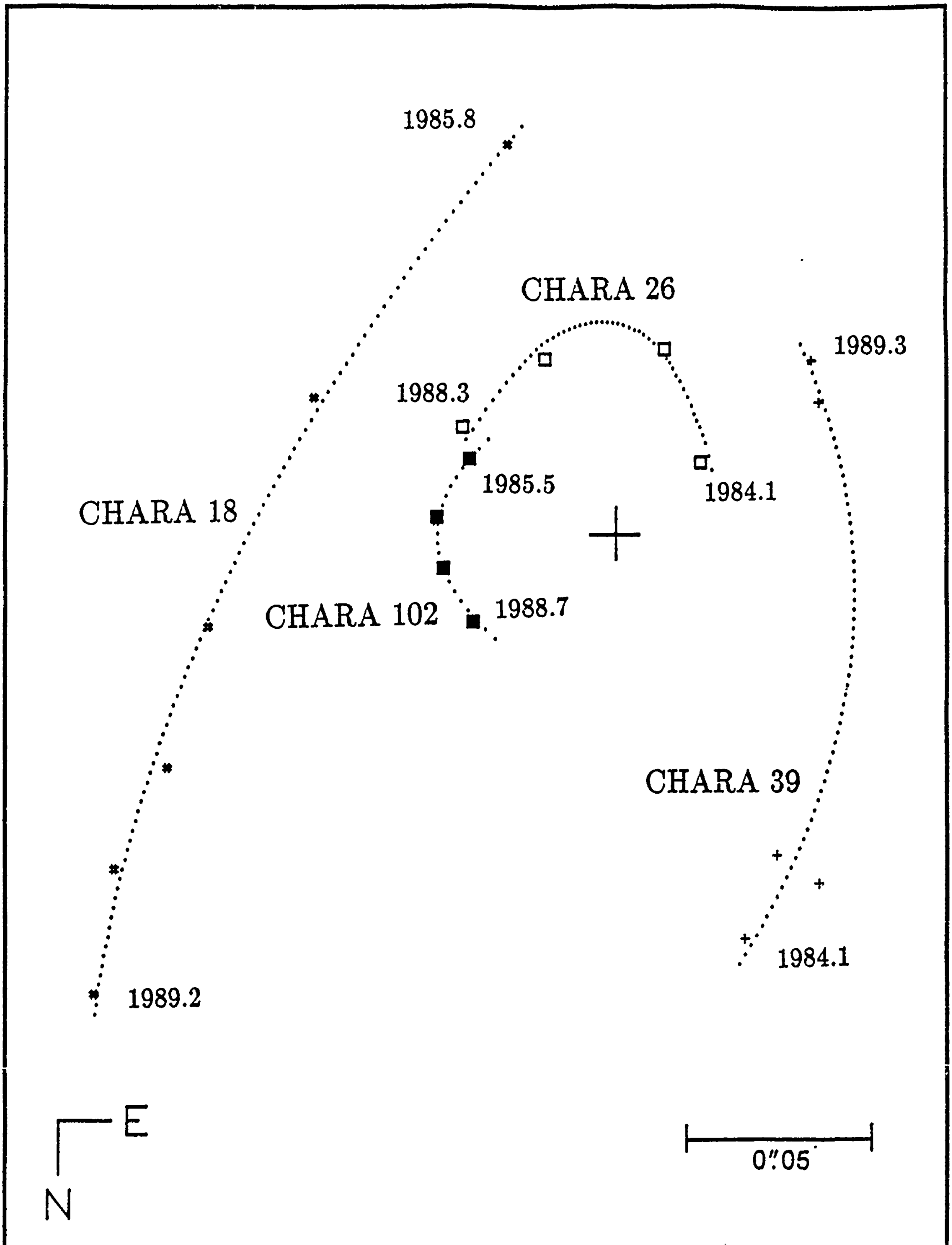
Figure Captions

Fig. 1. The motions of four rapidly moving CHARA systems are shown. (CHARA 18 = HR 1458, 26 = HR 2837, 39 = HR 4921, 102 = HR 8246). HR 1458 is a member of the Hyades group.

Fig. 2. The vector-autocorrelogram of the newly discovered companion to the visual binary HD 79699 clearly shows the double peak characteristic of the close companion designated as CHARA 144 Aa.



1985.8
CHARA 26
1989.3
1988.3
1985.5
1984.1
CHARA 18
1988.7
CHARA 102
CHARA 39
1984.1
1989.2
E
N
0"05

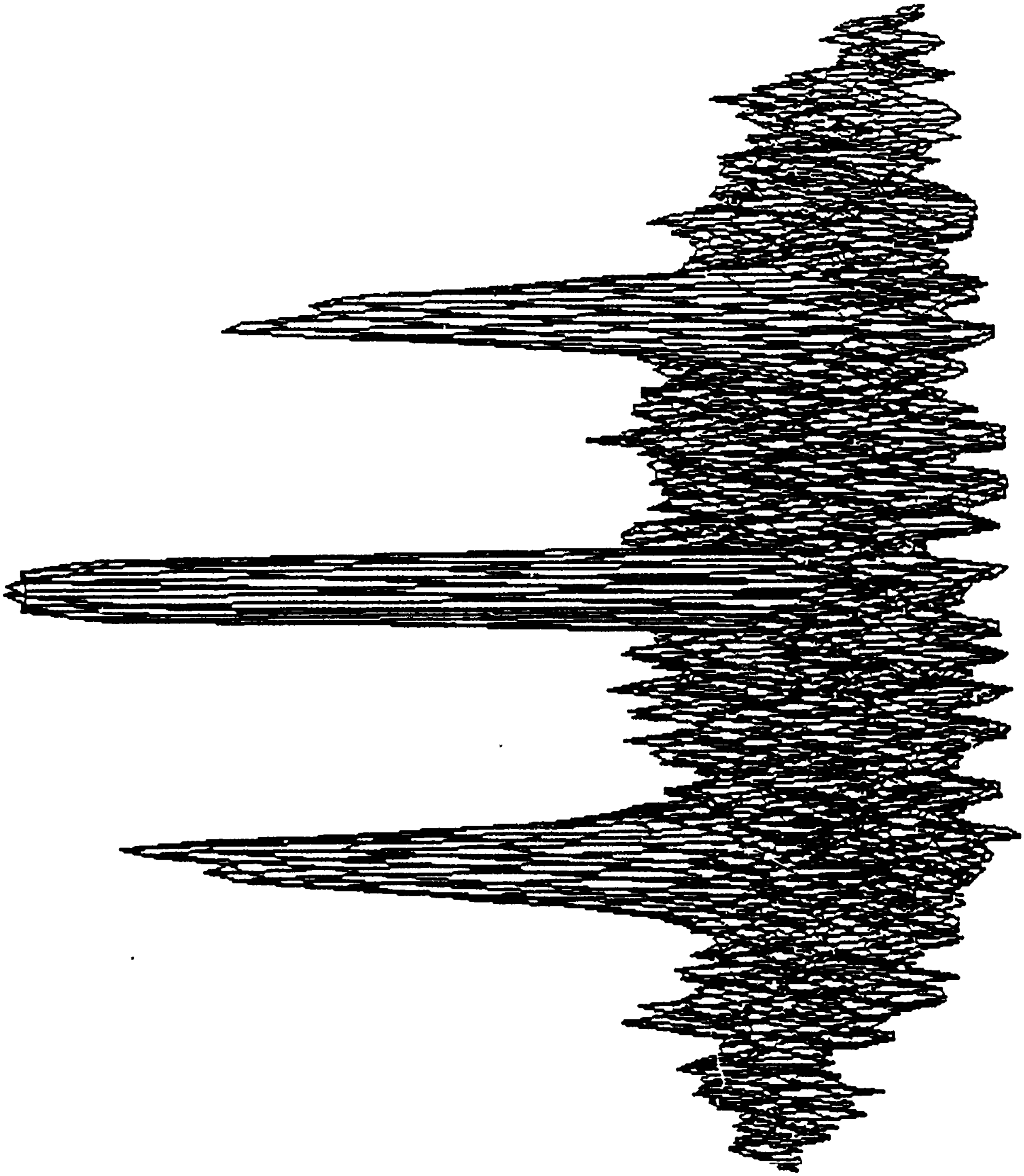


TABLE I. Newly Resolved Binary Stars

CHARA Number	HR/DM Number	Name	HD	SAO	ADS	α, δ (2000)	V	Spectral Classif.	Disc. Sep.	Binary Type
142 Aa	+29° 176	—	—	74496	887	01070+3014	8.9	G0	0.″089	Triple
143 Aa	−45°3892	—	68895	219602	—	08125−4616	6.7	B9V	0.045	Triple
144 Aa	−60°1353	—	79699	250485	—	09128−6055	6.1	B9V	0.021	Triple
145	+25°2191	—	86590	81134	—	10000+2433	7.9	G5	0.216	SB
146 Aa	HR 6027	ν Sco	145502	159763	9951	16120−1928	4.12	B2IV	0.063	Triple
147 Aa	−53°8153	—	150446	244095	—	16438−5330	9.2	B8/9IV+F/G	0.043	Triple
148	−45°12390	—	167954	228906	—	18197−4542	7.5	F7V	0.306	SB
149 Aa	+44°4464	—	222326	53242	16904	23392+4543	7.4	A2	0.048	Triple

00020+2706	ADS 17175	Bu 733 AB	224930	1988.6606	354°6	0″352
00024+1047	ADS 17180	A 1249	224994	1988.6605	231.0	0.240
00034+6339	HR 9097	CHARA 121	225094	1988.6552	38.1	0.189
00046+4206	ADS 30	CHARA 122 Aa	225218	1988.6552	90.5	0.108
00046+3416	ADS 32	STF 3056 AB	225220	1988.6552	143.0	0.713
00055+3406	ADS 51	Hu 1201 AB	39	1988.6580	308.1	0.082
00091+7943	ADS 102	STF 2	431	1988.6553	22.8	0.683
00095+1907	+18 0003	Cou 247	489	1988.6580	354.9	0.410
00104+5831	ADS 124	Bu 253	570	1988.6580	35.3	0.506
00108+5846	ADS 129	Bu 485	627	1988.6580	267.9:	0.130:
00119+2825	ADS 147	Bu 255	744	1988.6552	74.8	0.521
00122+5337	ADS 148	Bu 1026	761	1988.6552	257.1	0.105
00122+5337	ADS 148	CHARA 1 Aa	761	1988.6552	40.1:	0.190:
00130+0257	ADS 155	A 2001	866	1988.6580	155.4	0.335
00152+4406	ADS 197	A 1256 AB	1082	1988.6552	72.6	0.093
00163+7657	ADS 207	STF 13	1141	1988.6580	56.5	0.920
00173+0852	ADS 238	A 1803 AB	1317	1988.6552	130.8	0.125
00182+7256	ADS 243	A 803	1360	1988.6580	284.1	0.210
00206+1219	ADS 281	Bu 1015	1634	1988.6580	80.6	0.355
00214+6700	ADS 293	STT 6 AB	1658	1988.6552	155.2	0.667
00214+2744	ADS 295	Cou 347 Aa	1688	1988.6580	59.4	0.439
00243+5201	ADS 328	Hu 506	1976	1988.6552	51.6	0.164
00245+5632	ADS 332	A 908	236401	1988.6660	239.1	0.430
00283−2020	HR 108	B 1909	2475	1988.6578	203.1	0.068
00287+3718	ADS 382	A 1504 AB	2471	1988.6580	38.5	0.550
00298+6905	ADS 397	A 649	2549	1988.6580	319.5	0.428
00308+4732	ADS 416	Bu 394	2675	1988.6552	322.4	0.074
00318+5432	ADS 434	STT 12	2772	1988.6552	189.2	0.460
00320+2740	+26 0072	Cou 547	2854	1988.6580	209.1	0.094
				1988.6660	208.8	0.089
00321−0511	ADS 450	A 111 AB	2880	1988.6552	105.5	0.179
00335+4006	ADS 463	Ho 3	2993	1988.6552	115.8	0.277
00345+3015	+29 0099	Cou 654	—	1988.6660	215.6	0.238
00352−0336	ADS 490	Ho 212 AB	3196	1988.6552	42.7	0.218
00358+4901	ADS 493	STT 15	3210-1	1988.6552	319.0	0.217
00366+5608	ADS 504	A 914	3304	1988.6580	32.5	0.449
00402+4715	ADS 559	Bu 257	3700	1988.6660	247.8	0.647
00429+2047	ADS 597	A 2205	—	1988.6660	206.4	0.257
00444+6210	+61 0159	Mlr 26	4116	1988.6580	44.5:	0.215:
00448+6019	ADS 621	A 919 AB	4173	1988.6606	152.8	0.391
00504+5038	ADS 684	Bu 232 AB	4777	1988.6608	242.4	0.859
00516+2238	ADS 701	A 1808	4934	1988.6661	180.0	0.118
00520+3154	ADS 705	A 924	—	1988.6660	56.6	0.103
00532+0406	ADS 732	A 2307	5143	1988.6661	46.6	0.321
00542+4318	+42 0196	Cou 1654	5178	1988.6608	102.7	0.166
00546+1912	ADS 746	STT 20 AB	5267	1988.6661	208.3	0.476
00549+4924	ADS 749	Hu 802	5259	1988.6608	217.9	0.357
00550+2338	ADS 755	STF 73 AB	5286	1988.6661	282.3	0.701
00554+3040	ADS 768	Bu 500	5315	1988.6661	299.5	0.508
00568+6022	ADS 784	Bu 1099 AB	5408	1988.6553	327.5	0.251
00576+5424	ADS 795	Hld 4	5502	1988.6608	242.5	0.111
00583+2124	ADS 805	Bu 302	5641	1988.6661	168.9	0.416
00594+4057	+40 0199	Cou 1505	5729	1988.6608	137.5	0.203
01011+6021	ADS 832	A 926	5851	1988.6606	326.3	0.387
01014+1155	ADS 828	Bu 867	5988	1988.6661	6.5	0.412
01014+3535	+34 0164	Cou 854	5955	1988.6660	348.1	0.129
01015+6921	ADS 836	A 2901	5839	1988.6660	54.9	0.414
01023+0552	ADS 854	A 2003	6094	1988.6661	304.3	0.181
01029+5148	ADS 859	Bu 1161	6084	1988.6608	6.2	0.366
01030+4723	ADS 862	STT 21	6114	1988.6608	175.0	1.041
01037+5026	ADS 871	Hu 517	6194	1988.6608	27°1	0″566
01039+3528	ADS 873	Ho 213	6264	1988.6608	99.8	0.297
01049+3649	ADS 883	A 1515	—	1988.6608	289.7	0.242
01070+3014	ADS 887	A 929 AB	—	1988.6661	124.3	0.695
01070+3014	ADS 887	CHARA 142 Aa	—	1988.6661	111.0	0.089
01070+4744	ADS 916	A 931	6553	1988.6608	96.1	0.076
01071+3839	ADS 918	A 1516 AB	6586	1988.6608	83.1	0.138
01093+4715	ADS 940	STT 515	6811	1988.6553	132.7	0.490
01096+2348	ADS 955	Bu 303	6886	1988.6553	290.6	0.653
01100+5153	ADS 951	Hu 519	232385	1988.6661	130.0	0.372
01131+2942	ADS 993	A 1260	7255	1988.6635	45.3	0.229
01178+4946	ADS 1039	Hu 520	7695	1988.6635	165.7	0.313
01181+4707	ADS 1045	A 937	7759	1988.6635	218.5:	0.294:
01187+3245	+32 0229	Cou 663	7854	1988.6553	175.5	0.323
01198−0029	ADS 1081	Fin 337 BC	8036	1988.6553	276.2	0.110
01233+6808	ADS 1105	STF 115 AB	8272	1988.6554	283.8	0.073
01243−0655	ADS 1123	Bu 1163	8556	1988.6553	186.9	0.031
01258+2733	+26 0235	Cou 666	—	1988.6635	155.6	0.334
01280+5821	ADS 1156	A 940	236745	1988.6661	81.0	0.571
01296+2250	ADS 1183	A 1910 AB	9071	1988.6553	279.0	0.077
				1988.6635	278.1	0.077
01298+4547	+45 0359	Cou 1659	9031	1988.6635	25.9	0.300
01334+6820	HR 439	McA 3	9352-3	1988.6554	114.4	0.115
01342+3611	ADS 1224	A 1912 AB	9532	1988.6635	1.6	0.195
01371+4843	ADS 1263	A 817	9841	1988.6635	29.1	0.479
01373+4015	+39 0367	Cou 1214	—	1988.6635	176.0	0.311
01376−0924	HR 466	Kui 7	10009	1988.6553	345.3	0.126
01392+6436	ADS 1286	A 1266	10031	1988.6554	236.6	0.213
01405+5457	ADS 1309	A 1267	10146	1988.6554	3.2	0.273
01415+6240	ADS 1318	Kr 12	10196	1988.6635	293.6	0.418
01417+5323	ADS 1327	A 1268	10273	1988.6661	266.6	0.127
01425+5000	ADS 1341	B 2550 AB	—	1988.6661	274.9	0.229
01426+5001	ADS 1341	Hu 1210 CD	—	1988.6661	55.8	0.179
01449+1951	ADS 1375	A 2322	—	1988.6663	120.9	0.081
01450+2703	+26 0287	Cou 750	—	1988.6663	145.6	0.090
01465+2936	+28 0295	Cou 451	—	1988.6581	70.8	0.267
01472+4212	ADS 1410	A 1523	—	1988.6663	64.7	0.401
01492+4754	ADS 1438	CHARA 4 Aa	11031	1988.6554	37.1	0.153
01495+5645	ADS 1437	A 950 AB	236885	1988.6661	230.7	0.159
01510+2551	+25 0311	Cou 452	11245	1988.6581	180.6	0.288
01512+6021	ADS 1461	A 951	11126	1988.6661	218.7	0.450
01512+2439	ADS 1473	Ho 311	11284	1988.6581	319.2	0.110
01520+1326	ADS 1482	Hu 1213	11364	1988.6663	103.8	0.162
01551+2847	ADS 1522	STF 183 AB	11671	1988.6581	168.1	0.310
01563+4251	ADS 1537	A 1524 AB	11748	1988.6663	236.5	0.346
01570+3101	ADS 1548	A 819 AB	11849	1988.6581	208.7	0.308
01573+4812	ADS 1549	A 818	11826	1988.6661	205.6	0.300
01576+4433	ADS 1554	A 1526	11869	1988.6663	252.5	0.122
02009+6025	ADS 1592	A 956	12122	1988.6661	129.5	0.425
02016+4107	+40 0426	Cou 1510	—	1988.6663	131.7	0.377
02019+7054	ADS 1598	Bu 513 AB	12111	1988.6580	229.2	0.815
02021+4530	+44 0407	Cou 1665	—	1988.6663	102.6	0.501
02026+0905	+08 0316	McA 4	12483	1988.6554	143.1	0.229
02038+7013	+69 0129	Mlr 375	12300	1988.6580	208.0	0.217
02039+4220	ADS 1630	STT 38 BC	12534	1988.6554	107.0	0.575
02043+3924	+38 0401	Cou 1365	12592	1988.6663	129.5	0.195
02055+3018	+29 0357	Cou 455	—	1988.6663	98.5	0.452
02071+6957	ADS 1646	STF 204	12649	1988.6661	55.1	0.435
02090+3541	+34 0379	Cou 1067	13102	1988.6581	18.1	0.142
02097+0048	ADS 1680	A 2325	—	1988.6663	118.9	0.255

02107+4426	+43 0436	Cou 1667	—	1988.6663	73°5	0″152
02122+6132	+60 0448	Mlr 30	—	1988.6663	61.6	0.260
02128+3722	ADS 1701	Ho 497	13496	1988.6663	83.6	0.538
02145+6631	HR 640	McA 6	13474	1988.6581	110.0	0.055
				1988.6635	111.0	0.053
02157+2503	HR 657	Cou 79	13872	1988.6635	50.0	0.179
02160+4046	+40 0469	Cou 1669	13844	1988.6581	172.1	0.226
02183+4120	+40 0476	Cou 1670	14137	1988.6581	43.9	0.151
02186+4017	ADS 1763	Egg 2 Aa	14189	1988.6581	123.8	0.174
02198+0640	+06 0347	Vou 40	14416	1988.6608	113.8	0.211
02250+2529	+24 0344	Cou 357	14918	1988.6663	134.7	0.281
02257+6133	ADS 1833	STF 257	14817	1988.6581	53.4	0.354
02270+1952	ADS 1853	A 2328	—	1988.6663	79.9	0.424
02277+0426	ADS 1865	A 2329	15285	1988.6608	320.9	0.208
02279+4523	+44 0500	Cou 2011	15174	1988.6663	69.9	0.354
02280+0158	HR 719	Kui 8	15328	1988.6608	34.9	0.517
02290+6724	ADS 1860	CHARA 6 Ap	15089	1988.6581	141.8	0.295
02317+0244	ADS 1925	A 2333	15719	1988.6608	30.5	0.336
02333+5218	ADS 1938	STT 42 AB	15703	1988.6581	287.9	0.125
02361+7944	+79 0075	Mlr 449	15416	1988.6664	197.9	0.271
02363+4012	+39 0577	Baz	16097	1988.6663	71.3	0.315
02366+1226	HR 763	McA 7	16234	1988.6635	2.0	0.047
02377+6520	ADS 1976	Hu 1041	16036	1988.6663	86.4	0.191
02383+4604	ADS 1992	A 1278	16283	1988.6581	150.5	0.125
02384−0125	ADS 2005	A 450	16453	1988.6608	195.8	0.375
02393+2552	ADS 2010	A 2023	16486	1988.6663	227.3	0.594
02396−1153	HR 781	Fin 312	16620	1988.6554	176.4	0.075
02398+0009	ADS 2028	A 1928	16619	1988.6608	298.8	0.096
02409+3905	+38 0536	Cou 1371	—	1988.6663	308.5	0.164
02417+5529	ADS 2040	A 1280	16576	1988.6581	6.0	0.357
02422+4012	HR 788	McA 8	16739	1988.6581	79.4	0.048
				1988.6635	80.2	0.048
02423+4925	ADS 2051	Hu 539	16692	1988.6663	17.1	0.189
02424+2000	HR 793	μ Ari	16811	1988.6554	283.2	0.046
				1988.6635	279.8	0.050
02464+5738	ADS 2093	A 971	16952	1988.6664	51.3	0.190
02472+6551	+65 0290	Mlr 120	—	1988.6664	246.3	0.273
02500+2716	ADS 2159	McA 10 Aa	17573	1988.6582	203.9	0.230
02529+5300	ADS 2185	A 2906 AB	17743	1988.6664	133.6	0.186
02529+5300	ADS 2185	STF 314 AB,C	17743	1988.6664	311.6	1.575
02552+5950	+59 0567	Mlr 520	17911	1988.6664	333.8	0.114
03024+7236	ADS 2276	A 827	18424	1988.6664	253.4	0.213
03048+5330	HR 915	γ Per	18925	1988.6582	64.7	0.159
				1988.6636	64.3	0.158
03082+4057	HR 936	β Per Aa	19356	1988.6636	132.0	0.108
03143+1821	+17 0515	Cou 359	—	1988.6636	170.9	0.160
03266+2843	+28 0532	CHARA 9	21242	1988.6608	62.3	0.430
03337+5752	+57 0730	CHARA 117	21794	1988.6608	224.8	0.092
03423+3141	+31 0637	Cou 691	—	1988.6636	115.1	0.077
03465+2415	+23 0523	CHARA 12	23489	1988.6609	104.9	0.198
04008+0505	ADS 2928	A 1937	25248	1988.6582	205.2	0.149
				1989.2292	211.7:	0.174:
04044+2406	ADS 2965	McA 13 Aa	25555	1988.6636	337.1	0.041
04063+1952	+19 0662	CHARA 13	25811	1988.6609	52.2	0.073
04119+2338	+23 0635	CHARA 14	284163	1988.6609	109.9	0.126
04136+0743	ADS 3064	A 1938	26690	1988.6609	321.3	0.154
				1989.2291	329.6	0.132
04185+2135	HR 1331	McA 14 Aa	27176	1988.6554	16.2	0.095
				1988.6582	15.5	0.096
				1989.2292	0.9	0.111

04187+1632	ADS 3135	STT 79	27383	1989.2266	238°1	0″252
04256+1852	ADS 3210	Bu 1185	27989	1989.2266	208.2	0.219
04256+1557	HR 1391	Fin 342 Aa	27991	1988.6582	16.0	0.056
				1989.2292	18.5	0.066
04275+1113	ADS 3228	Bu 1186	28217	1989.2292	117.4	0.170
04286+1557	HR 1411	McA 15	28307	1988.6554	350.9	0.178
				1988.6637	350.4	0.181
				1989.2266	356.6	0.174
				1989.2292	352.1	0.164
04290+1610	ADS 3248	Hu 1080	28363	1989.2266	258.2	0.440
04298+1741	+17 0735	Cou 567	28436	1988.6636	18.3	0.142
04340+1510	+14 0721	CHARA 17	285931	1988.6609	69.5	0.177
04357+1010	ADS 3317	CHARA 18 Aa	29140	1988.6609	122.9	0.161
				1989.2292	130.4	0.185
04399+5329	ADS 3358	Bu 1295 AB	29316	1988.6637	39.2	0.040
04399+5329	ADS 3358	STF 566 AC	29316	1989.2294	219.1	0.732
04422+2257	HR 1497	McA 16	29763	1988.6609	318.7	0.198
				1989.2292	313.3	0.197
04432+5932	ADS 3391	A 1013	29606	1988.6637	256.6	0.161
				1989.2294	259.4	0.170
04465+4220	+42 1045	Cou 2031	30090	1988.6637	330.2	0.106
04506+1505	+14 0770	CHARA 20	30712	1988.6609	107.1	0.071
04512+1104	ADS 3475	Bu 883 AB	30810	1989.2266	263.2	0.111
04518+1539	ADS 3483	Bu 552 AB	30869	1989.2266	172.0	0.412
04536+2122	ADS 3501	CHARA 127 Aa	31033	1988.6609	115.7	0.093
				1989.2292	119.0	0.105
05167+4601	HR 1708	α Aur Aa	34029	1988.6610	289.6	0.045
05219+3934	+39 1272	Cou 2037	34807	1989.2374	141.4	0.363
05271+1758	ADS 4038	McA 19 Aa	35671	1988.6609	275.3	0.087
				1989.2374	272.7	0.093
05373+4404	+43 1315	CHARA 21	36948	1988.6609	57.3	0.128
				1989.2374	66.2	0.130
05386+3030	ADS 4229	Bu 1240 AB	37269	1988.6609	16.6	0.124
				1989.2294	14.2	0.129
05387−0235	ADS 4241	Bu 1032 AB	37468	1989.2294	137.6	0.254
05411+1632	ADS 4265	Bu 1007	37711	1989.2375	239.4	0.327
05417−0254	ADS 4279	Bu 1052	37904	1989.2375	15.4	0.446
05428−0649	ADS 4289	A 494 AB	38089	1989.2375	200.0	0.090
05446+1503	ADS 4323	STT 115 AB	38182	1989.2375	118.5	0.519
05449+2620	ADS 4324	A 496	38161	1989.2374	6.0	0.281
05484+2052	ADS 4392	STT 118 AB	38670	1989.2375	316.0	0.172
05573+3601	ADS 4532	Hu 1235	39924	1989.2274	126.1	0.124
06024+0939	ADS 4617	A 2715 AB	40932	1989.2294	203.8	0.360
				1989.2375	203.9	0.361
06034+1942	HR 2130	McA 24	41040	1988.6637	72.8	0.054
06041+2316	HR 2134	Kui 23 AB	41116	1989.2294	186.0	0.257
06074+2840	+26 1082	McA 25	41600	1988.6637	234.7	0.062
06105+2300	ADS 4768	Bu 1058	42216	1989.2375	233.3	0.222
06144+1754	HR 2214	Kui 24	42954	1989.2375	141.3	0.479
06159+0110	HR 2236	RST 5225	43358	1989.2375	266.6	0.161
06171+0957	ADS 4890	Fin 331 Aa	43525	1988.6637	82.9	0.073
				1989.2294	97.9	0.088
06200+2826	ADS 4929	Bu 895 AB	43885	1989.2375	128.8	0.264
06214+0216	ADS 4971	A 2667	44333	1989.2375	190.9	0.277
06221+5922	ADS 4950	STF 881 AB	43812	1989.2377	135.2	0.694
06252+0130	HR 2312	Fin 343	45050	1989.2377	354.0:	0.178:
06255+2327	+23 1346	CHARA 23	44926	1989.2294	154.5	0.119
06256+2320	HR 2304	McA 26	44927	1988.6637	145.6	0.076
				1989.2294	146.5	0.081
06289+2014	ADS 5103	BTZ Aa	45542	1989.2294	288.1	0.056

06383+2859	HR 2425	McA 27	47152	1988.6637	317°2	0".178
				1989.2294	315.7	0.185
06393+4200	ADS 5280	STT 150	47193	1988.6637	209 8	0.099
06474+1812	ADS 5447	STT 156	49059	1989.2377	230 5	0.384
06478+0020	ADS 5455	STT 157	49294	1989.2377	199 0:	0.387:
06492−0217	HR 2521	Fin 322	49643	1989.3082	48 4	0 154
06532+5928	ADS 5514	STF 963 AB	49618-9	1989.2295	273 4	0 246
06573+5825	ADS 5586	STT 159 AB	50522	1989 2295	58 5	0.213
06580+0218	+02 1483	CHARA 25	51566	1989.2294	39 0	0.929
				1989.3112	39 4:	0.918:
06581−2710	−26 03646	B 707	51925	1989 3082	19.0	0.245
06598+1557	ADS 5560	A 2461 AB	51911	1989.2295	329 4	0 328
07003−2207	ADS 5687	Fin 334 Aa	52437	1989.3082	17 8	0.055
07011+1146	ADS 5689	STT 163 AB	52309	1989 2295	71 6	0.123
07018−1118	ADS 5713	Hu 112	52721	1989.3083	194.6	0.649
07036+3941	ADS 5726	A 1959	——	1989 2295	341 3	0.250
07043+3734	+37 1645	McA 29	52823	1989.2295	180.2	0.187
07067−1117	ADS 5795	Bu 328 AB	53974	1989.3083	115 7	0.558
07079−1542	ADS 5814	A 3043	54336	1989.3083	302.3	0.233
07094−6023	−60 00782	HJ 3941	55527	1980 3083	275.5	0.473
07120−6311	−62 00789	HDO 199	56239	1989.3083	112 3	0.360
07143−2621	HR 2745	Fin 323	56014	1989.3083	141 6	0.129
07171−1201	ADS 5956	A 2123 AB	56593	1989.3083	155.9	0.351
07187−2457	HR 2782	Fin 313 Aa	57061	1969.3083	121 7	0.160
07205+0024	ADS 5996	STF 1074 AB	57275	1989.3112	169.9	0.669
07277+2127	ADS 6089	McA 30 Aa	58728	1989.2295	166.7	0.102
07324−3558	−35 03659	RST 4855	60312	1989.3057	136.6	0.055
				1989.3110	140 9	0.054
07334−2843	−28 04515	B 1066	60463	1989.3110	62.6	0.185
07336+1550	HR 2896	McA 32	60107	1989.2295	94.2	0.141
07352+3058	ADS 6185	STT 175 AB	60318	1989.2295	328.2	0.210
07364−5411	−53 01378	RST 2493	61435	1989.3083	303.4	0.284
07365−2520	−25 04775	B 729	61071	1989.3110	160.4	0.068
07374−3458	HR 2937	Fin 324 AB,C	61330	1989.3057	33.7	0.475
07374−3458	HR 2937	Fin 324 AB	61330	1989.3057	165.5	0.090
07387−0459	ADS 6245	A 535	61344	1989.3110	174.7	0.344
07417+3728	ADS 6276	STT 177	61600	1989.2268	161.5	0.427
07430−1704	ADS 6315	Hu 710	62351	1989.3057	83.4	0.419
07435−2711	−26 04850	B 737	62556	1989.3110	67.7	0.140
07441−1656	ADS 6327	Hu 844	62589	1989.3110	130.1	0.274
07443−2547	−25 04982	RST 2500	62681	1989.3110	311.4	0.320
07462+2108	ADS 6347	Ho 247	62720	1989.2268	236.2	0.415
07468−4648	−46 03421	Hu 1428	63449	1989.3057	26.8	0.482
07478−0332	−03 2065	RST 4375	63263	1989.3110	319.0	0.104
07486+2309	ADS 6378	WRH 15 AB	63208	1989.2268	46.2	0.279
07508−4652	−46 03487	RST 4866	64270	1989.3110	42.0	0.061
07508+0317	ADS 6405	A 2880	63799	1989.2268	329.8	0.059
				1989.3055	335.0	0.056
07513−0925	ADS 6412	Bu 1195	63976	1989.2267	92.1	0.170
				1989.3057	91.8	0.171
07518−1352	ADS 6420	Bu 101	64096	1989.2267	109.1	0.531
07528−3746	−37 04006	RST 4867	64547	1989.3110	251.6	0.203
07528−0526	HR 3072	Fin 325	64235	1989.2267	345.7	0.060
				1989.3057	345.6	0.070
07530−3318	−32 04516	RST 2508	64520	1989.3110	70.5	0.346
07561+2342	+24 1805	Cou 929	64704	1989.2268	164.8	0.172
07573−4753	−47 03457	I 26	65598	1989.3057	69.2	0.366
07573+0108	ADS 6483	STT 185	65123	1989.2268	105.1	0.134
				1989.3057	107.4	0.131
07599−4718	−46 03655	I 1070 AB	66079	1989.3110	2.5	0.269
08017−0836	ADS 6526	A 1580	66094	1989.3110	267°6	0".245
08017+6019	HR 3109	McA 33	65339	1989.2267	103 1	0.063
08043+3302	ADS 6549	STT 187	66299	1989.2268	352.2	0 367
08122+1740	ADS 6650	STF 1196 AB	68255-7	1989.2268	185 0	0.582
08125−4616	−45 03892	See 96 AB	68895	1989 3057	273 8	0 544
08125−4616	−45 03892	CHARA 143 Aa	68895	1989.3057	159 0	0 045
08128−6359	−63 00909	RST 310	69362	1989.3110	203 3	0.121
08144−4550	−45 03914	Fin 113 AB	69302	1989 3110	307 8	0 104
08199+0357	HR 3269	Fin 346	70013	1989.2268	68 9	0 271
				1989.3030	67 9	0 267
08210−3636	−36 04506	RST 4885	70504	1989.3110	340 4	0 201
08214−0136	ADS 6762	STF 1216	70340	1989.3030	284 0	0 524
08225−2942	−29 06041	B 1600	70725	1989 3110	280.1	0.338
08228−2621	ADS 6782	B 767 AB	70761	1989.3029	168.4	0 089
08250−4246	−42 04219	RST 4888	71302	1989 3110	113.0	0.434
08252−5528	−55 01543	RST 3593	71491	1989.3057	78 0	0 329
08267+2433	ADS 6811	A 1746 BC	71153	1989.2267	47 6	0 154
08275−5501	−54 01647	Fin 116	71919	1989.3057	43 3	0 126
08276−2051	HR 3335	B 2179	71581	1989.3030	214 3	0 417
08280−3507	−34 04842	Fin 314 Aa	——	1989.2180	60.3	0 118
08285−0230	ADS 6828	A 551 AB	71663	1989.2295	98 1	0 056
				1989.3030	99.3	0.051
08289−4811	−47 04000	RST 329	72090	1989 3110	104 6	0 362
08291−4756	−47 04004	Fin 315 Aa	72108	19[illegible] 3030	150.7	0.124
08291−4410	−43 04337	B 1101	72067	19[illegible] 3030	251.7	0.280
08315−1934	ADS 6862	I 489	72310	1989.3058	342.2	0 224
08331−2436	ADS 6871	Bu 205 AB	72626	1989.3030	331 6	0.543
08412+2028	ADS 6930	Bu 585	73871	1989.2378	85.9	0.469
08423−4806	−47 04251	RST 5304	74455	1989.3030	310 8:	0.497:
08468+0625	ADS 6993	SP AB	74874	1989.2296	258.3	0 208
08473−1703	ADS 6999	Bu 586	75098	1989 2295	127.1	0.141
				1989.3057	128.3	0.137
08486+0057	ADS 7012	A 2552	75207	1989.2295	102.0	0.160
08507+1800	ADS 7039	A 2473	75470	1989.2296	52.3	0.306
08526−3633	−36 05125	Fin 296	76072	1989.2783	83.7	0.081
08531+5458	ADS 7054	A 1584	75553	1989.2296	31.7	0.225
08539+1958	+20 2232	Cou 773	75974	1989.2296	44 5	0.221
08539+0149	ADS 7074	A 2554	76050	1989.2295	345 3	0.256
				1989.3031	346.7	0.260
08549+2613	ADS 7082	A 2131 AB	76095	1989.2296	209.1	0.395
08557+4141	ADS 7084	A 2132	76117	1989.2296	203.2	0.190
08585+3548	+36 1889	Cou 1897	76595	1989.2296	176.6	0.165
08594−2412	−23 07962	RST 2597	77073	1989.3085	40.5	0.141
09008+4148	HR 3579	Kui 37 AB	76943	1989.2296	252.4	0.484
09036+4709	ADS 7158	A 1585	77327	1989.2269	272.6	0.175
09082−2829	ADS 7205	B 177 AB	78590	1989.3085	197.1	0.157
09110−1929	ADS 7225	I 824	79034	1989 3085	55.8	0.182
09123+1459	HR 3650	Fin 347 Aa	79096	1989.2269	149.9	0.153
				1989.2296	150.4	0.154
				1989.3031	148.9	0.153
09128−6055	−60 01353	HDO 207 AB	79699	1989.3030	239.4	0.234
09128−6055	−60 01353	CHARA 144 Aa	79699	1989.3030	34.8	0.021
09168−2157	−21 2745	I 493	80032	1989.3085	86.4	0.505
09180+2835	ADS 7284	STF 3121	79969	1989.2296	244.6	0.268
09207−2913	ADS 7318	I 198	80752	1989.3085	257.7	0.106
09229−0951	ADS 7334	A 1342 AB	81009	1989.2269	34.7	0.159
				1989.3030	36.3	0 154
09243−3926	−38 05541	Fin 348	81411	1989.3031	190.5	0.105
09245+1808	ADS 7341	A 2477	81163	1989.2269	339 5	0.405
09264−4215	−41 05091	B 1122	81782	1989.3031	206.1	0.163

09267−2847	ADS 7379	JC 5	81753	1989 3031	275°0	0″549
09273−0913	ADS 7382	A 1588 AB	81728	1989 2269	195 6	0.367
				1989.3031	195.5	0.374
09278−0604	HR 3750	B 2530	81809	1989.2269	326.6	0.409
				1989.3031	327 2	0.412
09285−2426	ADS 7394	B 181	81982	1989.3085	278 0	0.175
09285+0904	ADS 7390	STF 1356	81858	1989.2269	52 1	0.459
09289−3750	−37 05811	B 1125	82120	1989.3086	122 6	0.098
09326+0151	HR 3794	Fin 349	82543	1989 2269	183.2	0.152
				1989.3031	184 0	0.152
09330−2705	−26 07184	RST 1436	82725	1989.3085	144 3	0.252
09366−2442	−24 08263	Fin 383	83261	1989.3031	151 6	0.117
09372−3721	−36 05822	RST 2644	83416	1989.3086	235.2	0.198
09372−5340	−53 02646	See 115	83520	1989 3031	186.8	0.654
09379+4554	ADS 7457	A 1765	83158	1989.2378	151 4	0.125
09398−5008	−49 04578	RST 4917	83879	1989.3031	41.2:	0.570:
09442−2746	HR 3871	Fin 326	84367	1989.3031	242.1	0.087
09455−2824	ADS 7510	B 188	84566	1989.3085	104 0	0.075
09474+1134	HR 3880	McA 34	84722	1989.2269	35.2	0.056
09477+2036	+21 2108	Cou 284	84739	1989.2296	56.4	0.138
09482−4632	−45 05435	B 1661	85080	1989.3086	51.8	0.166
09498+2111	HR 3889	Kui 44	85040	1989 2271	208 1	0.194
09506−3252	−32 06799	RST 2656	85384	1989.3085	275.0	0.287
09512+3629	ADS 7541	Ho 369 AB	85177	1989.2297	102.0	0.400
09521+5404	ADS 7545	STT 208	85235	1989.2297	180 5	0.181
09525−0806	ADS 7555	AC 5 AB	85558	1989.2378	72.9	0.553
				1989 3031	73 2	0.554
09566+4359	+44 1931	Pop 151	85973	1989.2297	79 7	0.502
09579−6045	−60 01548	Fin 152	86674	1989.3113	257 5	0.409
10000+2433	+25 2191	CHARA 145	86590	1989.2271	37.7	0.216
10004−0731	−06 3055	RST 3673	86733	1989.3085	158.1	0.336
10008−5308	−52 03033	RST 1474	87027	1989.3086	93.6	0.156
10030−3016	−29 08037	Daw 99	87232	1989.3114	234.6:	0.288:
10043−2823	ADS 7629	I 292	87416	1989.3058	331.1	0.439
10052−2812	ADS 7635	I 293	87556	1989.3058	323.4	0.154
10066−3511	−34 06425	RST 2670	87782	1989.3114	94.0	0.311
10074−1943	ADS 7647	Bu 218	87840	1989.3058	137.5	0.550
10083+3137	ADS 7651	Kui 48 AB	87822	1989.2271	350.9	0.092
				1989.2296	350.7	0.091
10092−4743	−47 05578	RST 472	88222	1989.3113	120.1	0.316
10093+2020	ADS 7662	A 2145	88021-2	1989.2296	142.0	0.057
10095−6841	−68 01034	I 13 AB	88473	1989.3086	115.4	0.660
10105−4235	−41 05656	B 1151	88379	1989.3113	186.5	0.367
10115−3924	−38 06260	I 1523	88505	1989.3113	131.0	0.195
10117+1321	ADS 7674	Hu 874	88355	1989.2269	280.6	0.124
10120−2836	ADS 7681	B 194	88522	1989.3058	153.8	0.080
10121−0613	ADS 7675	Ho 44	88478	1989.3058	205.8	0.557
10122−2716	ADS 7683	B 195	88538	1989.3058	290.6	1.097
10135−5145	−51 04578	RST 5517	88842	1989 3086	201.1	0.490
10161−5954	−59 02008	Hu 1597	89263	1989.3086	52.0	0.216
10163−2859	ADS 7706	I 851	89117	1989.3058	246.2	0.341
10163−4624	−45 05913	B 1153	89191	1989.3113	35.4	0.405
10163+1744	ADS 7704	STT 215	88987	1989 2378	181.6	1.397
10182−5049	−50 05024	Hu 1598	89463	1989 3113	231.4	0.317
10222−4520	−44 06427	RST 4926	89987	1989.3113	265.3	0.280
10223−3225	−31 08206	I 1525	89949	1989.3114	200.9	0.175
10238−4415	−43 06224	I 208 AB	90201	1989.3113	16.0	0.659
10259−5637	−55 03419	RST 2692	90551	1989 3113	165.4:	0.333:
10260+0256	ADS 7769	A 2570	90361	1989.2378	307.5	0.329
				1989.3058	306.9	0.325

10263−5820	−57 03213	RST 3697	90616	1989 3113	296°7	0″265
10269+1931	+20 2486	Cou 292	90460	1989 2296	234 1	0.212
10270+1713	ADS 7775	STT 217	90444	1989 2296	145 1	0.569
10275+0334	ADS 7779	STT 218	90572	1989 3058	127 6	0.492
10279+3643	ADS 7780	Hu 879	90537	1989.2296	237 1	0.287
10282−2548	ADS 7787	Fin 308 AB	90737	1989.3058	190.2	0.115
10297−4352	−43 06308	B 1158	91036	1989.3113	322 1	0.080
10309−3616	−35 06481	RST 3701	91153	1989.3113	146 4	0.168
10311−2411	ADS 7809	CHARA 132 Aa	91172	1989.2269	192 8	0.073
10329−3956	−39 06476	Fin 26	91460	1989.3113	169 8	0.271
10345−3721	−36 06489	RST 3706	91673	1989.3113	58.6	0.115
10362+0041	ADS 7845	J 84	91814	1989 3058	38.4	0.577
10366−2846	ADS 7852	I 857	91955	1989.3114	264.8	0 267
10388−4245	−42 06390	Fin 338	92328	1989.3032	34.4	0.207
10392−0553	ADS 7866	A 66	92283	1989.3059	139.5	0.683
10406−5342	−53 04053	Fin 40	92615	1989 3086	241.8	0 280
10408−3750	−37 06718	RST 2702	92590	1989.3059	217.8	0.400
10423−3612	−35 06668	JSP 418	92791	1989.3059	301.9	0 227
10427+0335	ADS 7896	A 2768	92749	1989 2271	294.6	0 326
				1989.3032	294.6	0.320
10431−5414	−53 04080	Fin 41	92979	1989.3086	54.1	0.664
10447−3809	−37 06769	B 794	93122	1989 3059	175.8	0.240
10455−2602	ADS 7918	I 502 AB	93227	1989.3059	354.4	0 270
10465−6416	−63 01649	Fin 364	93549	1989.3032	86.3:	0.041:
10468−4907	−48 05918	RST 508	93513	1989.3086	30.1	0.565
10481+4107	ADS 7929	STT 229	93457	1989.2271	275.6	0 761
10520+1606	ADS 7952	A 2373	94120	1989.2379	78 1:	0 107:
10525−1838	ADS 7960	Hu 460	94254	1989.3059	26 5	0 529
10553−3530	−34 07078	I 1206 AB	94693	1989.3059	302.6	0 143
10565−5452	−54 04182	Fin 173	94921	1989.3086	42.8:	0 375:
10581−5420	−53 04262	Hu 1601	95139	1989.3086	8.1	0.266
10582−3540	−35 06865	B 1175	95091	1989.3059	246.4	0 601
10585+1711	ADS 7997	A 2375	95037	1989 2379	201.1	0.359
11005−5022	−49 05748	B 1695	95473	1989.3086	176.1	0 352
11008+2913	+29 2110	Cou 960	95342	1989 2297	107.0	0.189
11009−4030	−39 06845	Fin 365	95506	1989 3032	98.0	0 123
11011−5212	−51 05233	RST 1553 AB	95582	1989 3086	122.0	0 278
11050+3825	ADS 8047	Ho 378	96016	1989.2378	55.9	0.980
11053−2718	HR 4314	Fin 47	96202	1989.2379	223.2	0.114
				1989.3032	222.8	0.110
11068−7050	−70 01304	B 2006	96705	1989.3087	184.1	0.192
11085−5030	−49 05862	RST 528	96845	1989 3086	351 5	0.416
11100+1443	+15 2297	Hei 60	96953	1989.2379	260.0	0.355
11113−7428	−73 00810	I 874	97473	1989 3087	79.2	0.456
11118−3449	−34 07272	RST 5352	97327	1989.3060	159.8	0 282
11124−1830	ADS 8086	Bu 220	97411	1989.2378	326.5	0.301
				1989.3033	326.5	0.318
11133−5007	−49 05943	RST 4940	97592	1989.3059	101.2	0 459
11136+5525	ADS 8092	A 1353	97455	1989 2297	222.6	0.484
11137+2008	ADS 8094	STF 1517	97561	1989 2271	324.6	0.477
11141−1526	ADS 8096	Bu 916	97635	1989 3087	130.3	0.242
11148−2830	−27 07953	RST 5353	97785	1989.3060	70.1	0.135
11154+4728	ADS 8104	Hu 639	97773	1989.2297	87.3	0.123
11158+4227	+43 2096	Cou 1904	97857	1989.2297	200.9	0.367
11168−0509	ADS 8114	A 5	98079	1989.3114	306 8	0.322
11170−5537	−54 04436	Fin 181	98192	1989.3032	336.2	0.318
11191−3100	−30 09107	I 506	98415	1989 3114	148.6	0.803
11191+3811	HR 4380	CHARA 133	98353	1989 2271	131.2	0.096
				1989.2297	131.3	0.097
11209−6408	−63 01885	RST 537	98743	1989.3059	120.1	0.628

11216−4949	−49 06089	RST 538	98794	1989.3060	207°7	0″692
11219−3415	−33 07668	Vou 25	——	1989.3060	242.9	0.462
11231+0408	ADS 8145	A 2776 AB	98914	1989.2379	112.3	0.106
				1989.3087	112.8	0.106
11255−0751	ADS 8155	A 137	99307	1989.3114	95.2	0.486
11268−5310	−52 04567	I 883	99574	1989.3032	358.9	0.135
11279−0142	HR 4419	RST 4944	99651	1989.2378	286.1	0.225
				1989.3033	286.4	0.227
11283−7228	HR 4425	B 1699	99872	1989.3032	352.2	0.379
11290−2446	ADS 8176	B 215	99837	1989.3060	195.1	0.541
11297−0619	ADS 8182	A 7	99917	1989.3087	212.6	0.205
11308−5849	−58 03677	Fin 187	100122	1989.3059	263.0	0.318
11308+4117	ADS 8189	STT 234	100018	1989.2271	142.9	0.397
11317−5445	−54 04591	Fin 44	100252	1989.3114	77.8	0.733
11322+3615	ADS 8198	Hu 1134	100235	1989.2271	122.4	0.125
				1989.2297	122.5	0.126
11324+6105	ADS 8197	STT 235	100203	1989.2297	281.3	0.569
11352−2033	−19 3302	B 1701	100707	1989.3114	210.4	0.557
11363+2747	ADS 8231	STF 1556 AB	100808	1989.2272	144.4	0.635
11371−4942	−49 06332	RST 4947	101004	1989.3059	202.5:	0.268:
11379−3634	−35 07340	I 509	101096	1989.3114	11.8	0.549
11383−6322	−62 02168	I 422 AB	101205	1989.3032	111.6	0.362
11395−6524	−64 01685	B 1705 AB	101379	1989.3032	238.9	0.240
11430−3933	−38 07286	RST 5358	101822	1989.3060	178.8	0.166
11431−3601	−35 07393	I 1546	101834	1989.3060	38.3	0.104
11441−0448	−03 3167	RST 5524	101969	1989.3114	66.0	0.081
11446−4925	−48 06770	RST 3558 AB	102077	1989.3059	298.7	0.416
11447−0431	−03 3169	RST 4484	102059	1989.3114	63.5	0.734
11479−1528	ADS 8309	A 2380	102513	1989.3087	56.3	0.210
11495−4604	−45 07312	Fin 366	102703	1989.3060	172.7	0.228
11510−0520	HR 4544	McA 36	102928	1989.3033	28.0	0.136
11520+4806	ADS 8325	Hu 731	——	1989.2382	312.7	0.872
11523−1958	−19 3360	B 1708	103116	1989.3060	143.9	0.214
11529−3354	−33 08018	HJ 4478	103192	1989.3033	26.7	0.709
11532−1540	ADS 8332	A 2579	103228	1989.3087	56.0	0.375
11540−5652	−56 04859	RST 2772	103345	1989.3088	310.5	0.241
11546−3208	−31 09335	I 1215	103450	1989.3062	230.7	0.655
11548−4224	−41 06843	I 79	103480	1989.3087	94.2	0.466
11551+4629	ADS 8347	A 1777 AB	103483	1989.2272	201.9	0.099
11552−5012	−49 06618	RST 562 AB	103526	1989.3088	327.4:	0.258:
11557−1438	−13 3473	RST 3761	103595	1989.3060	92.8	0.108
11568−3820	−37 07562	B 1202	103759	1989.3087	36.0	0.359
11578−4343	−43 07386	B 1203 AB	103910	1989.3087	225.9	0.226
11579−2430	ADS 8366	RST 3763 AB	103918	1989.3060	301.5	0.391
11596−7813	−77 00772	HJ 4486	104174	1989.3088	200.9	0.465
12002−2706	ADS 8380	B 218	104224	1989.3062	339.3	0.550
12010+4347	ADS 8392	A 1779	104334	1989.2380	29.2	0.599
12018+4728	+48 1992	Cou 1752	——	1989.2380	83.9	0.166
12022−5232	−51 06290	RST 570	104533	1989.3114	223.9	0.661
12061+6842	ADS 8419	STF 3123 AB	105122	1989.2272	278.7	0.187
12064−6543	−65 01788	Fin 367 Aa	105151	1989.3033	42.7	0.155
12080+4242	ADS 8433	A 1998	105369	1989.2380	355.1	0.388
12108+3954	ADS 8446	STF 1606	105824	1989.2272	227.1	0.299
12137−2719	ADS 8463	B 221	106271	1989.3062	106.3	0.364
12141−3644	−36 07723	See 147 AB	106338	1989.3062	2.3	0.334
12160+4807	ADS 8485	Hu 736	106689	1989.2382	216.2	0.263
12165−5009	−49 06957	RST 583	106725	1989.3088	80.7	0.174
12178−3606	−35 07842	R 193	106922	1989.3033	155.5	0.045
12199−0040	HR 4689	McA 37	107259	1989.2271	157.1	0.118
				1989.3033	160.1	0.119

12216−2716	ADS 8525	B 227	107539	1989.3062	178°8	0″063
12229−5223	−51 06636	RST 588	107719	1989.3114	156.3	0.380
12232−3729	−36 07814	RST 2793	107783	1989.3033	206.1	0.138
12238+5410	ADS 8535	STT 249 AB	107922	1989.2272	264.4	0.401
12244+4306	ADS 8540	STT 250	108005	1989.2272	345.8	0.380
12247−2004	−19 3483	B 1716	108012	1989.3114	220.5	0.721
12261−0429	ADS 8548	Bu 922	108240	1989.3060	121.4	0.480
12267−0535	ADS 8551	A 78	108320	1989.2297	167.1	0.134
				1989.3060	168.4	0.125
12270−0332	ADS 8552	A 79 AB	108361	1989.3060	109.1	0.169
12274−2843	ADS 8555	B 228	108410	1989.3062	150.9	0.169
12299−5015	−49 07142	RST 4960	108749	1989.3087	352.4:	0.117:
12324−4742	−47 07683	RST 599	109089	1989.3087	284.1	0.416
12325−5954	−59 04296	JSP 539	109091	1989.3088	223.4	0.152
12332−6057	−60 04128	B 802	109164	1989.3115	176.0	0.446
12344−4708	−46 07998	RST 3798	109369	1989.3088	81.9	0.378
12357−1650	ADS 8603	Fin 368 Aa	109557	1989.3035	115.5	0.136
12358−6150	−61 03303	RST 4503	109517	1989.3088	77.9	0.129
12362−4650	−46 08027	RST 5526	109607	1989.3088	163.5:	0.070:
12369−3211	−31 09797	I 1222 AB	109696	1989.3115	221.5	0.351
12392−4022	−39 07742	B 1215	109961	1989.3115	71.0	0.174
12397−3717	−36 07990	Daw 63	110035	1989.3115	7.0	0.486
12421−5446	−54 05306	Fin 200	110372	1989.3033	267.5	0.403
12422+2622	ADS 8635	A 1851	110465	1989.2382	269.2	0.505
12446−5717	−56 05410	Fin 65	110698	1989.3033	140.4	0.153
12463−6050	−60 04277	B 1722	110925	1989.3115	349.7	0.261
12528−3919	−38 08056	B 1216	111882	1989.3115	297.3	0.261
12533+4246	+43 2270	Cou 1579	——	1989.2382	36.0	0.227
12533+2115	ADS 8695	STF 1687 AB	112033	1989.2297	172.3	1.044
12550−8507	−84 00407	RST 2819	111482	1989.3033	238.0	0.686
12564−0057	ADS 8708	STT 256	112398	1989.3115	96.4	0.986
12567−4741	−47 07972	I 83	112361	1989.3115	226.6	0.789
12572+0818	+09 2696	Fin 380	112503	1989.2272	157.0	0.175
12575+2457	+25 2578	Cou 397	112572	1989.2382	63.9	0.630
12597−0348	ADS 8727	CHARA 39 Aa	112846	1989.2272	121.5	0.066
				1989.3035	130.1	0.071
13000−4123	−40 07615	I 1224	112833	1989.3088	11.6	0.146
13029+1328	ADS 8751	STF 1711	113322	1989.2382	339.7	0.511
13032−5607	−55 05348	Fin 64	113237	1989.3115	261.3	0.489
13039−0340	ADS 8759	Bu 929	113459	1989.2297	199.9	0.690
				1989.3115	199.9	0.691
13040−1737	ADS 8764	Bu 798	113460	1989.3116	165.5	0.225
13069+5200	ADS 8785	A 1605	234012	1989.2382	167.3	0.996
13074−5952	−59 04740	R 213	113823	1989.3115	21.9	0.731
13100−0532	ADS 8801	McA 38 Aa	114330	1989.2272	331.6	0.469
				1989.3035	331.9	0.467
13100+1731	ADS 8804	STF 1728 AB	114378-9	1988.6652	189.3:	0.101:
				1989.2272	11.6	0.051
13103−3447	−34 08695	B 2015	114336	1989.3115	295.9	0.103
13117−2633	HR 4978	Fin 305	114576	1989.3033	99.3	0.178
13134−5042	−50 07589	I 1227	114772	1989.3035	198.1	0.206
				1989.3062	198.2	0.205
13134+5252	ADS 8825	A 1607	115002	1989.2382	21.0	0.470
13140−4849	−48 08036	RST 628	114854	1989.3088	189.9	0.169
13141−3323	−32 09215	B 2016	114907	1989.3062	358.9	0.300
13145−2417	ADS 8831	Fin 297 AB	114993	1989.3062	149.4	0.225
13149−1026	−09 3648	RST 3830	115078	1989.3116	89.3	0.150
13167+5034	ADS 8843	STT 263	115477	1989.2382	135.6	1.834
13179−6830	−67 02237	HDO 224	115286	1989.3062	208.8	0.727
13191−5239	−51 07425	I 516	115595	1989.3116	189.6:	0.220:

13202+1747	ADS 8863	A 2166	115955	1989.2300	353°6	0″117
13218−5525	−54 05559	I 924	115990	1989.3116	95.3	0.693
13225+4242	+43 2324	Cou 1581	116377	1989.2300	160.0	0.274
13226−6059	−60 04627	Fin 208 AB	116087	1989.3036	133.7	0.178
13229−4757	−47 08260	SLR 18	116197	1989.3035	241.1	0.697
13229−7209	HR 5030	B 1736	115967	1989.3036	300.8	0.198
13248−3438	−33 09020	I 220	116536	1989.3116	16.2	0.295
13258+4430	ADS 8901	A 1609 AB	116878	1989.2300	319.4	0.293
13266+3235	+33 2337	Cou 787	——	1989.2382	151.5	0.333
13271−4909	−48 08202	Fin 351	116836	1989.3035	158.7	0.185
13320−6519	−64 02441	Fin 369	117432	1989.3036	164.5	0.099
13320+3109	+31 2500	Wor 24	——	1989.2382	260.8	0.263
13342−1623	−15 3694	RST 3844	117968	1989.3116	4.5	0.119
13343+3044	+31 2508	Cou 600	——	1989.2382	55 8	0.557
13348−1313	ADS 8954	Bu 932 AB	118054	1989.2300	52.9	0.367
				1989.3035	52.9	0.365
13388−5737	−56 05856	Fin 339	118520	1989.3035	20.5	0.184
13396+1044	ADS 8937	Bu 612 AB	118889	1989.2273	228.4	0.283
13400+3759	ADS 8938	Hu 897	——	1989.2279	33.1	0.388
13415−2327	ADS 8994	Fin 352 AB	119086	1989.2299	318.7	0.197
				1989.3035	320.3	0.206
13437−4204	−41 08089	Fin 353 AB	119361	1989.3035	48.0	0.117
13455−4910	−48 08459	RST 653	119632	1989.3088	206.3	0.302
13461−5218	−51 07723	I 1235	119725	1989.3116	35.2:	0.578:
13461+0507	ADS 9019	STF 1781	119931	1989.2273	156.9	0.507
13472−0943	HR 5178	Kui 65	120033	1989.2273	238.3	0.295
				1989.3035	238.3	0.295
13479−4910	−48 08487	I 933	120000	1989.3116	199.3	0.603
13520−3137	−31 10706	Bu 343	120759	1989.3036	0.9	0.456
13535−4138	−41 08231	B 1233	120960	1989.3063	303.5	0.069
13539−1440	−13 3786	RST 3852	121136	1989.3036	105 6	0.118
13539−1910	ADS 9043	Hu 898	121137	1989.3063	236.6	0.137
13550−4235	−41 08263	I 401 AB	121207	1989.3063	280.3	0.348
13553−2524	ADS 9055	I 936	121330	1989.3063	218.7	0.495
13566−3519	−34 09254	B 2019	121526	1989.3063	328.3	0.093
13569−4907	−48 08613	I 937	121502	1989.3090	210.9	0.539
13574−6229	−61 04194	Fin 370	121454	1989.3036	212.1	0.102
13579−4905	−48 08632	RST 670	121657	1989.3116	130.0	0.169
14000−6026	−59 05331	JSP 608	121878	1989.3116	341.0	0.246
14013−4835	−47 08803	RST 676	122159	1989.3090	85.3	0.292
14020+5713	ADS 9039	A 1097 AB	122740	1989.2300	230.0	0.429
14023−5233	−51 07911	RST 2884	122277	1989.3090	37.2	0.111
14027−5040	−50 08206	RST 5531	122356	1989.3116	48.8	0.244
14029+1417	+14 2691	Hei 65	122654	1989.2382	118.4	0.461
14031−6030	−59 05359	JSP 612	122311	1989.3090	301.5	0.099
14036−5140	−51 07922	RST 679	122496	1989.3116	328.7:	0.520:
14037+0829	ADS 9094	Bu 1270	122769	1989.2300	134.9	0.104
14046−3539	−35 09242	I 941	122776	1989.3063	170.8	0.353
14063−2635	ADS 9106	Bu 938	123107	1989.3063	312.2	0.244
14082+3645	ADS 9121	STT 276 AB	123670	1989.2382	205.3	0.490
14087−5133	−50 08285	B 1236	123372	1989.3090	211.3	0.392
14113+3013	+30 2488	Cou 605	——	1989.2382	172.2	0.310
14120+4411	ADS 9159	STT 278	124399	1989.2300	306.7	0.329
14124+2843	ADS 9158	STT 277 AB	124346	1989.2300	44.3	0.289
14138+0859	ADS 9169	A 1100	124492	1989.2383	173.0	0.298
14138+3100	+31 2596	Cou 606	——	1989.2382	126.2	0.156
14141+1258	HR 5323	CHARA 41	124570	1989.2273	131 9	0.184
14142−0831	ADS 9170	Bu 999 AB	124497	1989.3063	57 7	0.425
14153+0308	ADS 9132	STF 1819	124757	1989.2383	221.7	0.879

14160−0704	ADS 9186	Hu 138	124851	1989.3063	9°0	0″498
14180+6914	ADS 9220	A 1102	125725	1989.2300	100.4	0.400
14187+6409	+64 0993	Mlr 168	——	1989.2383	115.8	0.244
14188−5841	−58 05464	I 523	125015	1989.3090	61.6	0.293
14189+0354	ADS 9215	STF 1832 AB	125377	1989.2383	152.7	0.429
14189+5452	HR 5372	CHARA 137	125632	1988.6653	6.0	0.083
				1989.2273	1.7	0.069
14213+3050	+31 2612	Cou 482	——	1989.2383	120.5	0 613
14220+5107	ADS 9238	A 148	126126	1989.2383	5.3	0.629
14234+0827	ADS 9247	Bu 1111 BC	126128	1989.2274	70.7	0.230
14241+1617	+16 2642	McA 39	126269-0	1989.2273	160.0	0.049
14252−2808	ADS 9256	STN 31	126279	1989 3116	267.9	0.591
14262−4523	−44 09323	I 402	126354	1989.3062	186.0	0.164
14268+1625	ADS 9264	A 2069	126695	1989 2383	244.1	0.240
14272−3647	−36 09366	B 1246	126557	1989.3063	156.6	0.386
14277−4113	−40 08692	I 1243 AB	126622	1989.3063	302.9	0.258
14282−2929	ADS 9270	Fin 306 AB	126769	1989.3036	102.9	0.084
14303+4709	+47 2153	Cou 1917	——	1989.2383	27.8	0.339
14310−0548	−05 3896	RST 4529	127352	1989.3090	10.9	0.255
14323+2641	ADS 9301	A 570	127726	1989.2273	239.0	0.181
14339+2949	ADS 9313	AGC 6	128042	1989 2383	134.8	0.782
14340+4113	+41 2512	Cou 1437	——	1989.2383	34.8	0.161
14358+0015	ADS 9318	Bu 941 AB	128233	1989.2383	147 9	0.244
				1989.3090	147 8	0.242
14369+4813	ADS 9324	A 347	128718	1989.2273	265.3	0.571
14373−4608	−45 09302	Fin 318 Aa	128266	1989.3037	339.4	0.160
14373+0217	ADS 9323	CHARA 42 Aa	128563	1988 6653	176.3:	0.176:
				1989.2274	175.6	0.159
				1989.3036	177.2	0.156
14380−8000	−79 00770	I 524	127283	1989.3091	85.2	0.357
14381+5135	ADS 9329	STF 1863	128941	1989.2273	66.7	0.659
14383−4954	−49 08904	Fin 371	128415	1989.3037	42.0	0 101
14399−2140	−21 3942	RST 2915	128832	1989.3090	309.7	0.527
14400−5300	−52 07393	B 1252	128636	1989.3090	318.3	0.348
14401+0504	ADS 9334	A 1107	129006	1989.2274	86.0	0.455
14403+2158	HR 5472	McA 40	129132	1989.2273	52.7	0.048
				1989.2300	54.4	0.038
14411−2237	−21 3946	RST 2917	129065	1989.2300	180.7	0.395
				1989.3090	181.4	0 387
14411+1344	ADS 9343	STF 1865 AB	129246-7	1989.2300	302.6	0.924
14416+2747	+28 2360	Cou 407	129411	1989.2383	120.4	0.381
14417−4415	−43 09246	Hu 1510	129035	1989.3118	146 0	0.516
14435−6258	−62 04257	B 1759 AB	129092	1989.3037	79.3	0.243
14447−2029	−19 3950	B 1761	129714	1989.3118	159.1:	0.198:
14449−3259	−32 10342	I 1253	129682	1989.3118	315.9	0.326
14453−3609	−35 09765	I 528	129732	1989 3036	1.4	0 043
14455+4222	ADS 9378	STT 285	130188	1989 2273	309.7	0.357
14459+2343	+24 2770	Cou 100	——	1989 2300	287 3	0 141
14462−2110	HR 5504	Fin 309	129980	1989 2300	321 4	0.279
				1989.3036	322.4	0 283
14479−6831	−67 02652	I 235	129750	1989 3037	116.2	0.413
14489+0557	ADS 9392	STF 1883	130604	1989.2300	286.4	0 602
14492−1050	ADS 9395	Hu 141	130558	1989 2274	115.4	0 317
				1989.3090	115.9	0.315
14493+1014	ADS 9397	A 2983	130669	1989.2247	212.0	0 078
				1989 2301	212.8	0.076
				1989 3063	212.8	0 076
14497+0800	ADS 9400	A 1110 AB	130726	1989 2301	246.6	0 641
14501−4151	−41 09194	I 1256	130543	1989 3090	119 0	0 267
14516−4335	−43 09391	Fin 319	130807	1989.3037	68.3	0 074

14542−6625	−65 02914	HJ 4707	130940	1989.3091	302°2	0″653
14545−3921	−38 09753	I 1578	131388	1989.3090	356 0	0.247
14548+2411	+24 2795	Cou 409 Aa	——	1989.2383	214 8	0.505
14565+0255	ADS 9443	A 2172	131954	1989.3090	171 9	0.085
14566−6222	−61 04768	B 2026	131491	1989.3037	291.4	0.125
14567−6247	−62 04337	Fin 372	131492	1989.3037	50 4	0.070
14584−4507	−44 09742	I 1579	132016	1989.3118	291 5	0 501
14587−2739	ADS 9453	Bu 239	132219	1989.2300	353 0	0 568
				1989.3036	353 3	0.567
14588+3551	+36 2560	Cou 1136	132583	1989.2301	124.1	0.154
14590+0059	ADS 9459	A 2173	——	1989.2383	133 0	0.275
14593+4649	+47 2190	Cou 1760	——	1989.2384	213.0	0.214
14595+1753	+18 2966	Cou 188	——	1989.2383	224 6	0.282
15006−5230	−51 08653	RST 2932	132352	1989.3091	286 0	0.271
15010−4300	−42 09898	B 1256	132515	1989.3064	83.0	0.650
15016−4223	−41 09390	I 1263	132621	1989.3064	206.5	0.305
15018+0008	ADS 9490	Bu 348 AB	132933	1989.2274	109 4	0.504
				1989.3091	109 6	0.503
15031+4439	HR 5612	CHARA 43	133484	1989.2247	116.9	0.083
15035−4035	−40 09221	I 1262	133022	1989.3064	187.7	0.302
15038−3819	−37 09898	B 828	133098	1989.3064	310.4	0.303
15039+4739	ADS 9494	STF 1909	133640	1989.2385	47 4	1.583
15047−5625	−55 06331	RST 2937	133044	1989.3091	182.9	0.183
15051−4703	HR 5605-6	HJ 4728	133242-3	1989.3063	69.0	1.643
15053−1936	−19 4016	RST 3907	133489	1989.3091	120.6	0.065
15071−0217	ADS 9504	A 689	133928	1989.3091	313.9	0.306
15078+3956	+40 2856	Cou 1271	134303	1989.2384	168.4	0.376
15088+4013	+40 2859	Cou 1272	——	1989.2384	46.0	0.277
15088−4517	HR 5626	See 219	133955	1989.3064	206.2	0.232
15089−0610	ADS 9515	RST 4534 AB	134213	1989.2274	11.8:	0.382:
15100+2751	+28 2407	Cou 410	——	1989.2384	149.6	0.344
15116+1008	ADS 9530	A 1116	134827	1989.2301	46.9	0.771
15121+1858	HR 5654	Cou 189	134943	1989.2274	144.0	0.464
15123−1947	ADS 9532	B 2351 Aa	134759	1989.3091	305.7	0.122
15127+6008	ADS 9545	Hu 1159	135529	1989.2384	336.0	0.242
15136+3453	ADS 9547	Ho 60	135365	1989.2301	164.0	0.086
15142−3830	−38 10086	B 1274	134990	1989.3118	64.9	0.684
15155−4913	−48 09757	I 960	135132	1989.3091	112.9	0.842
15157−2736	ADS 9552	Bu 350	135390	1989.3064	121.1	0.420
15183+2649	ADS 9578	STF 1932 AB	136176	1989.2301	254.9	1.514
15185−4753	HR 5683	HJ 4753 AB	135734	1989.3063	131.3	1.121
15186−4612	−45 09814	I 1267	135768	1989.3064	37.3	0.468
15186−7828	−78 00972	RST 2943	134583	1989.3091	102.8	0.472
15192+4329	ADS 9589	A 1630	——	1989.2384	248.0	0.776
15193−5532	−55 06490	RST 2949	135784	1989.3091	253.6	0.250
15197−2416	ADS 9586	HJ 4756	136121	1989.3118	266.2	0.656
15200+2338	+24 2847	Cou 103	——	1989.2383	283.2	0.544
15210+2104	ADS 9600	Hu 146	136596	1989.2383	128.4	0.640
15227−4441	HR 5708	Cop AB	136504	1989.3064	187.4	0.269
15232+3018	ADS 9617	STF 1937 AB	137107-8	1989.2384	23.9	1.018
15233+4022	+40 2878	Cou 1441	——	1989.2301	17.3	0.256
15234−5919	−58 05908	HJ 4757	136415	1989.3118	19.8	0.830
15246−4835	−48 09912	B 1288 AB	136807	1989.3063	323.5	0.187
15246+5413	ADS 9628	Hu 149	137588	1989.2301	272.0	0.615
15251−2340	−23 12272	RST 2957	137153	1989.3091	269.4	0.224
15251−3810	−37 10225	RST 2955	137015	1989.3064	228.3	0.149
15259+6032	+61 1505	Mlr 346	——	1989.2384	34.4	0.264
15268+2840	+29 2667	Cou 484	137739	1989.2384	71.2	0.292
15270−2432	−24 12077	RST 4541	——	1989.3064	208.4	0.308
15272+1804	ADS 9642	A 2073	137740	1989.2383	113.8	0.290
15272+4133	+42 2601	Cou 1443	137896	1989 2247	177°7	0″507
15278+2906	HR 5747	β CrB	137909	1988.6653	129.6	0.188
				1989 2275	119.1	0.134
15282+0251	ADS 9654	A 2175	137844	1989.2385	195.4	0.279
				1989.3091	195.6	0.276
15288−3129	−31 11981	I 239	137728	1989.3064	304.8	0.326
15307+3810	ADS 9682	Hu 1163	138439	1989.2274	68.4	0.108
15313−3349	−33 10564	HWE 78 AB,C	138138	1989.3064	131 2	1 548
15318+4053	ADS 9688	A 1634 AB	138629	1989.2385	18.3	0.057
15329+3121	HR 5778	Cou 610	138749	1989.2275	200.9	0.737
15347+2655	+27 2513	Cou 798	——	1989.2275	74.1	0.113
15351−4110	HR 5776	HJ 4786	138690	1989 3119	277.5	0.699
15361+3948	ADS 9716	STT 298 AB	139341	1989.2247	305.0	0.284
15363−3851	−38 10497	B 1299	138875	1989.3119	27.6	0.201
15368−0438	−04 3930	RST 4545	139177	1989.3118	273.0	0.438
15390+2545	+26 2712	Cou 612	139749	1989.2275	240.8	0.205
15399−1947	ADS 9735	Bu 122	139628	1989.2385	223.3	1.821
15405+1841	ADS 9742	A 2076	139939	1989.2384	181.2	0.682
15406+3128	+31 2762	Cou 613	140065	1989.2384	344.6	0.258
15413+5959	ADS 9756	STF 1969	140590	1989.2384	23.5	0.661
15416+1941	ADS 9744	Hu 580 AB	140159	1988.6653	65.9	0.166
				1989.2275	67.0	0.186
15420+0028	ADS 9747	A 2176	140122	1989.3091	86 5	0 073
15420+4204	+42 2629	Cou 1445	140432	1989.2247	225 9	0.077
15424+6113	+61 1531	Mlr 48	140811	1989.2384	101 3	0.309
15428+2618	ADS 9757	STF 1967	140436	1989 2275	117.4	0 566
15430−3442	−34 10497	See 245	140075	1989.3119	342.2	0.580
15431+1340	ADS 9758	Bu 619	140438	1989.2384	5.4	0 712
15440+2220	+22 2878	Cou 106	140629	1989.2275	272.5	0.399
15442−4913	−48 10247	I 1274	140147	1989.3119	21.3	0.227
15443−5419	−53 06667	I 1099	140080	1989 3119	18.0	0.442
15451+2936	+30 2703	Cou 614	140889	1989 2384	38.7	0.328
15453−5841	−58 06252	Fin 234 AB	140178	1989 3119	169.3	0.225
15454−3738	−37 10479	B 846	140517	1989.3119	175.4	0.434
15457−2245	−22 4020	B 2367	1406[illegible]	1989.3092	9.2	0.051
15462−2804	ADS 9775	Bu 620 AB	140[illegible]	1989.3092	171.4	0.570
15468−5807	−57 07206	I 974	1[illegible]	[illegible]89.3119	163.1	0.088
15469+1904	ADS 9783	A 2077	[illegible]	[illegible]89.2384	231.0	0.555
15474+5929	ADS 9794	A 1127	141[illegible]	1989.2247	288.4	0.324
15486+4949	+50 2219	Cou 1918	234[illegible]	1989 2384	186.7	0.326
15489−5424	−54 06692	Fin 61	1409[illegible]	1989.3119	214.8:	0.520:
15492+6032	ADS 9806	Hu 912	142089	1988.6653	4.8	0.060
15513−0305	HR 5895	CHARA 51	141851	1989.2275	178.3	0.088
				1989.3092	173 8	0.083
15519−1232	ADS 9812	Hu 153	141898	1989.3118	69.8	0.425
15529−4937	−49 10089	I 1278	141765	1989.3119	342.6	0 298
15543−3404	−33 10796	B 1308	142187	1989.3119	274.2	0 467
15550−1923	ADS 9834	Hu 1274	142378	1989.2385	120.9	0 561
				1989.3118	120.6	0 552
15554−4320	−42 10904	B 1309	142278	1989.3119	346.5	0.134
15557−2645	ADS 9836	I 977	142456	1989.3092	184.2	0.228
15599−7802	−77 01181	I 333	141846	1989.3120	331 6	0.556
16003−2237	HR 5953	δ Sco	143275	1989.3038	200.8	0.068
16028−6002	−59 06554	JSP 680	143286	1989.3064	104 9	0.194
16044−1122	ADS 9909	STF 1998 AB	144069-0	1989.2385	39.9	0.760
16048−4044	−40 10171	I 1284	143941	1989.3065	1 0	0.060
16054−1948	ADS 9913	Bu 947 AB	144218	1989.3038	142.9:	0 344:
16054−1948	ADS 9913	McA 42 CE	144218	1989.3038	121.0	0 092
16057−0617	ADS 9918	Fin 384 Aa	144362	1989.2275	158.9	0 043
				1989.3038	152.6	0.043

16065−4027	−40 10189	RST 1876	144259	1989.3038	281°1	0″285
16077−2124	−21 4270	McA 43	144641	1989.3038	327.6:	0.056:
16085−3155	−31 12593	B 1316	144734	1989.3065	265.3	0.234
16085−1006	ADS 9932	Bu 949	144892	1989.2275	194.8	0.473
16094−3103	−30 12880	I 557	144926	1989.3065	238.7	0.129
16115+0943	HR 6032	Fin 354	145589	1989.2275	84.1	0.115
16120−1928	ADS 9951	Bu 120 AB	145502	1989.3065	1.9	1.302
16120−1928	ADS 9951	CHARA 146 Aa	145502	1989.3065	164.8	0.063
16137+4638	ADS 9975	A 1642	146327	1989.2385	190.4	0.515
16159−4918	−48 10656	RST 5539	145946	1989.3065	56.2	0.352
16192+4140	ADS 10006	STT 309	147275-6	1988.6598	289.8	0.313
				1989.2277	289.4	0.310
16193−3529	−35 10877	See 272	146745	1989.3038	272.1	0.247
16193−4240	−42 11188	See 271	146667	1989.3037	66.1	0.233
16205−2008	ADS 10005	B 1808 AB	147104	1989.2275	183.0	0.210
				1989.3038	181.8	0.209
16212−2536	HR 6084	σ Sco Aa	147165	1989.2275	81.3	0.416
				1989.3038	81.4	0.414
16229−1701	−16 4280	CHARA 54	147473	1989.2275	74.9	0.155
				1989.3038	78.1	0.155
16238+6141	ADS 10052	STF 2054 AB	148374	1989.2277	352.3	1.041
16241−6256	−62 05308	B 1809	147158	1989.3064	286.3	0.164
16245−3734	−37 10778	B 868	147628	1989.3038	101.9	0.039
16271−3729	−37 10800	B 872	148121	1989.3093	300.4	0.211
16273−7305	−72 01946	B 2041	147320	1989.3093	56.0	0.312
16283−1613	−15 4324	RST 3950	148394	1989.2275	57.6	0.269
				1989.3121	55.5	0.272
16294−2626	ADS 10074	α Sco	148478	1989.3037	275.5	2.857
16317−0215	ADS 10095	A 693	148943	1989.3120	244.3	0.134
16318−0702	ADS 10092	STF 3105	148931	1989.3120	196.7	0.393
16345−6502	−64 03515	B 1815	148724	1989.3093	236.6	0.385
16420+7353	+74 0680	Mlr 198	151746	1989.2277	151.7	0.118
16422+4112	ADS 10169	STF 2091	150903	1988.6598	317.7	0.574
16425−3705	−36 10916	R 283	150420	1989.3092	265.3	0.541
16438−5330	−53 08153	Fin 251 AB	150446	1989.3093	281.0	0.372
16438−5330	−53 08153	CHARA 147 Aa	150446	1989.3093	36.6	0.043
16443−5834	−58 06879	Fin 250	150407	1989.3093	155.1	0.363
16453−3238	−32 11984	B 2043	150896	1989.3092	283.4	0.181
16466−4705	−46 11019	B 1825 AB	150958	1989.3093	246.4	0.303
16468−1320	−13 4504	RST 3959	151238	1989.3120	199.8	0.173
16475−4528	−45 10941	HDO 260	151113	1989.3093	356.3	0.500
16478−4356	−43 11112	I 1595	151183	1989.3093	101.1	0.199
16490−3344	−33 11465	B 1828	151470	1989.3092	221.9	0.093
16515+0113	ADS 10230	STT 315	152127	1989.2277	332.8	0.319
				1989.3065	333.1	0.322
16533+4725	HR 6286	CHARA 58	152812	1989.2277	132.0	0.198
16540−4148	−41 11024	B 1833 AB	152234	1989.3093	76.7	0.504
16544−2734	ADS 10244	B 322	152454	1989.3092	47.8	0.258
16547−4334	−43 11222	B 1836	152335	1989.3093	57.8	0.368
16555−2134	ADS 10257	Bu 241	152655	1989.3065	11.3	0.373
16584+3943	+39 3062	Cou 1289	153527	1989.2277	84.7	0.078
16596−4117	−41 11145	B 1839 AB	153157	1989.3120	204.0	0.212
17011−4204	−41 11171	B 1841	153382	1989.3120	2.2	0.157
17018−5108	−50 10955	I 1306	153370	1989.3038	10.7	0.219
17081−4137	−41 11282	I 407	154569	1989.3120	168.7	0.163
17081+3555	ADS 10360	Hu 1176 AB	155103	1988.6599	73.5	0.095
				1989.2277	54.9	0.076
17082−0105	ADS 10355	A 1145	154895	1989.3040	7.6	0.507
17083+5051	ADS 10369	CHARA 60 Aa	155328	1989.2277	357.9	0.149
17093−2954	ADS 10357	B 330	154883	1989.3121	86.4	0.150

17096−4302	−42 11880	B 1848	154809	1989.3120	88°6	0″194
17103−1926	−19 4547	McA 46	155095	1989.3040	115.0	0.137
17108−3134	−31 13656	B 1330	155081	1989.3121	66.2	0.097
17112−5156	−51 10728	RST 3073	154925	1989.3120	297.1	0.311
17113−4611	−46 11267	RST 5541	155020	1989.3120	93.4	0.151
17116−1629	ADS 10385	Hu 169	155317	1989.3121	2.2	0.115
17121+4544	+45 2505	Kui 79 AB	155876	1989.2385	196.4	0.751
17146+1423	ADS 10418	CHARA 139 Aa	156014	1989.2277	116.6	0.162
17155−3836	HR 6398	Fin 355	155826	1989.3038	99.1	0.125
17157−0949	ADS 10423	A 2592	156034	1989.3040	216.0	0.341
17158−3344	−33 11887	See 322	155889	1989.3040	294.1	0.193
17173−3010	−30 13996	Bu 1119	156184	1989.3040	257.7	0.324
17178−3406	−33 11934	B 1333	156200	1989.3120	18.7	0.152
17194−4413	−44 11595	HDO 269	156398	1989.3038	29.7	0.118
17195−5004	−49 11324	Fin 356	156331	1989.3038	30.5	0.038
17217+3958	HR 6469	McA 47	157482	1988.6599	162.4	0.103
				1989.2305	170.1	0.101
17221−7007	HR 6411	Fin 373	156190	1989.3066	280.9	0.104
17240−0921	−09 4546	RST 3972	157498	1989.3121	353.8	0.096
17241+3834	ADS 10531	Hu 1179	157853	1988.6654	283.5	0.125
				1989.2305	282.7	0.133
17283−2058	ADS 10561	A 2244	158122	1989.3121	97.6	0.255
17294−3831	−38 11927	B 342	158156	1989.3123	99.7	0.505
17303−0103	ADS 10598	STF 2173	158614	1989.2303	333.8	1.086
17305−1446	ADS 10595	Hu 177	158561	1989.3121	275.7	0.142
17308−3726	−37 11639	B 912	158409	1989.3121	106.5	0.239
17317−4845	−48 11785	See 331	158426	1989.3123	235.3	0.346
17323+2849	ADS 10621	A 352	159240	1988.6654	2.2	0.141
17326+3445	ADS 10624	Hu 1181	159304	1988.6654	140.1	0.102
17335−4224	−42 12245	B 1862	158846	1989.3123	331.1	0.257
17335+5734	HR 6560	Mlr 571	159870	1988.6654	339.4	0.132
17366+0722	ADS 10659	A 1156	159857	1988.6654	356.5	0.109
17368−2058	ADS 10657	Hu 751	159663	1989.3066	257.2	0.105
17370+2753	+27 2853	Kui 83 AB	——	1988.6654	238.4	0.262
				1989.2303	227.0	0.258
17375−3747	−37 11727	B 915 AB	159632	1989.3066	275.3	0.159
17375+2419	HR 6571	CHARA 63	160181	1988.6654	49.9	0.080
				1989.2303	44.5	0.072
17399−0039	ADS 10696	Bu 631	160438	1988.6654	117.1	0.136
				1989.2277	114.8	0.141
				1989.2303	114.1	0.140
				1989.3121	114.5	0.138
17447−4244	−42 12431	Fin 341	160928	1989.3066	190.5	0.086
17450−1646	−16 4610	Vou 42	161227	1989.3121	346.1	0.230
17471+4737	HR 6641	CHARA 64	162132	1989.2305	123.7	0.191
17490+3704	+37 2949	Cou 1145	162338	1989.2305	164.8	0.049
17499+0031	ADS 10819	A 2186	162232	1989.3121	281.5	0.159
17521−2654	ADS 10837	I 1343	162437	1989.3066	264.9	0.216
17533−3444	−34 12200	Bu 1123	162586	1989.3040	57.0	0.253
17534−3454	−34 12203	See 342	162587	1989.3040	221.5	0.396
17539−3445	−34 12226	B 1871	162724	1989.3040	280.4	0.171
17541−4820	−48 12133	B 1870	162551	1989.3066	57.3	0.078
17542−3553	−35 12034	B 1346	162762	1989.3094	169.3	0.523
17543−2558	ADS 10870	B 363	162871	1989.3094	45.6	0.319
17543+1108	HR 6676	Fin 381	163151	1988.6655	157.1	0.056
				1989.2305	130.4	0.058
17554−3851	−38 12311	I 1345	162944	1989.3094	188.0	0.469
17555−4759	−47 11904	B 1873	162842	1989.3066	43.4	0.111
17563+0259	ADS 10899	A 2189	163471	1989.3066	353.0	0.108
17564+1820	ADS 10905	McA 49 Aa	163640	1988.6655	70.3	0.089

17571+0004	ADS 10912	STF 2244	163624	1989.3040	92°7	0″385
17572+2400	HR 6697	McA 50	163840	1988.6655	350.6	0.105
17574−1804	ADS 10909	A 2254	163535	1989.3096	168.6	0.294
17584−5510	−55 08388	RST 956	163260	1989.3094	199.1	0.494
17584+0427	+04 3562	Kui 84	—	1988.6655	270.6	0.134
17593−3600	−35 12129	RST 5445	163724	1989.3094	83.7	0.290
18009−2413	−24 13745	RST 3147	164146	1989.3094	204.7	0.227
18044−5952	−59 07214	RST 5099	164328	1989.3066	257.3	0.214
18059+2126	ADS 11060	STT 341 AB	165590	1989.2305	91.8	0.497
18061−2207	−22 4557	B 1877	165287	1989.3094	231.4	0.535
18071−4949	−49 11933	I 1350	165127	1989.3094	207.8	0.602
18078+2606	ADS 11089	CHARA 67 Aa	166045	1988.6655	124.3	0.165
18090−3617	−36 12259	RST 3155	165728	1989.3066	14.0	0.222
18095−2621	ADS 11100	B 381	165952	1989.3094	51.3	0.236
18095+0401	ADS 11111	STF 2281 AB	166233	1989.3040	312.8	0.401
18101−2346	−23 14005	RST 5104	166107	1989.3094	163.3	0.233
18108−3529	−35 12338	B 1352	166136	1989.3066	161.4	0.230
18117+33[illegible]	ADS 11149	B 2545 AB	166988	1988.6655	73.5	0.093
				1989.2305	75.1	0.088
18133−03[illegible]4	−03 4254	RST 4583	166993	1989.3096	82.6	0.386
18136−4430	−44 12422	I 1355	166619	1989.3094	210.0	0.477
18146−3654	−36 12361	B 935	166970	1989.3066	110.5	0.094
18164−4028	−40 12327	I 1020	167297	1989.3068	280.9	0.439
18167−2032	−20 5068	McA 51	1675[illegible]	1989.3041	134.7	0.251
18176−2752	ADS 11224	B 386	16770[illegible]	1989.3068	30.1	0.520
18180+1347	HR 6851	CHARA 68	168199	1988.6655	42.6	0.059
				1989.2385	45.2	0.052
18197−4542	−45 12390	CHARA 148	167954	1989.3068	51.5	0.306
18211+7244	HR 6927	χ Dra	170153	1989.2385	225.9	0.142
18234−3844	−38 12745	I 1364	168800	1989.3068	260.7	0.064
18236−2610	ADS 11296	Ho 566	168991	1989.3068	329.8	0.440
18280+0612	HR 6928	CHARA 71	170200	1988.6655	103.1	0.079
18301+0404	ADS 11399	CHARA 72 Aa	170580	1988.6655	177.8:	0.139:
				1989.3040	181.4:	0.148:
18303−2533	ADS 11395	B 394	170398	1989.3066	189.5	0.225
18338−3248	−32 14255	I 1025	170994	1989.3068	215.3	0.319
18352+1812	HR 6977	CHARA 74	171623	1988.6656	21.4	0.143
18362−3311	−33 13379	I 637	171418	1989.3068	114.7	0.336
18368−2617	−26 13320	RST 3187	171595	1989.3068	222.1	0.225
18384−0312	ADS 11520	A 88 AB	172088	1989.3040	273.0	0.102
18413+3018	ADS 11579	STF 2367 AB	172865	1988.6656	87.9	0.180
18429−3917	−39 12836	I 1379	172579	1989.3068	159.9	0.178
18439−0013	ADS 11614	A 859	173160	1989.3096	15.0	0.251
18444+3937	ADS 11635	CHARA 77 Ca	173607	1989.3041	29.4	0.044
18455+0530	ADS 11640	Fin 332 Aab	173495	1988.6655	125.1	0.107
18455+0530	ADS 11640	Fin 332 Bab	173495	1988.6655	137.8	0.151
18487−1836	HR 7072	Kui 88	173928	1989.3041	163.8	0.436
18594−1250	HR 7166	Kui 89	176162	1989.3041	320.2	0.114
19026−2953	ADS 11950	HDO 150 AB	176687	1989.3041	305.9	0.212
19098−2101	−21 5275	Fin 311 AB	178524	1989.3041	178.6	0.126
19098−1948	ADS 12096	B 427	178555	1989.3041	250.3:	0.105:
19155−2515	ADS 12214	B 430	179950	1989.3041	111.5	0.133
19200−1435	−14 5390	RST 4037	181191	1989.3068	22.3	0.166
19294−4057	−41 13536	B 1385	183023	1989.3068	316.2	0.175
19296−1239	ADS 12505	Hu 75	183347	1989.3096	299.1	0.449
19307+2758	ADS 12540	McA 55 Aa	183912	1988.6575	159.0	0.406
19360−3648	−37 13265	I 651	184439	1989.3068	139.7	0.757
19377−4127	−41 13605	Vou 34	184732	1989.3068	135.9	0.160
19394+3009	HR 7473	McA 57	185734	1988.6575	170.8 ?	0.022 ?
19398−2326	ADS 12741	See 389	185404	1989.3068	337.5	0.081

19401−3137	−31 16935	Fin 13	185386	1989.3068	81°2	0″632
19407−0037	ADS 12775	CHARA 88 Aa	185762	1989.3096	340.6	0.084
19487+1852	+18 4252	McA 58	187321-2	1988.6575	98.7	0.415
19531−1436	HR 7571	CHARA 90	187949	1989.3069	181.0	0.261
19553−0644	ADS 13104	STF 2597	188405	1989.3123	290.5	0.251
19598−0957	HR 7637	Ho 276	189340	1988.6628	65.5	0.174
20045+4814	HR 7684	CHARA 91	190781	1988.6575	207.3	0.358
20073−5127	−51 12382	RST 1059	190444	1989.3069	126.8	0.151
20157+5014	HR 7755	CHARA 93	192983	1988.6575	185.8	0.158
20158+2749	HR 7744	McA 60 Aa,B	192806	1988.6575	142.6	0.281
20189+3817	ADS 13686	A 1425 AB	193443	1988.6630	268.2	0.149
20202+3924	ADS 13728	A 1427 AB	193702	1988.6630	110.9	0.337
20222+3115	ADS 13760	A 1208	193986	1988.6630	156.2	0.282
20232+2052	ADS 13777	A 288	194113	1988.6630	226.1	0.115
20246+5527	+54 2344	Mlr 588	194719	1988.6630	237.2	0.225
20247−0846	−09 5457	RST 4062	194233	1988.6630	359.8	0.251
20251+5935	ADS 13850	A 730	194882	1988.6631	318.6	0.218
20253+6001	+59 2231	Mlr 433	194933	1988.6630	150.1	0.238
20262+3547	+35 4115	Cou 2130 Aa	194760	1988.6630	63.4	0.155
20309−1503	HR 7837	Fin 336	195330	1988.6630	245.4	0.109
20311+3332	+33 3930	Cou 1962	—	1988.6630	276.9	0.188
20311+1548	ADS 13944	A 1675	195481	1988.6630	182.3	0.074
20312+1116	ADS 13946	CHARA 99 Aa	195482	1988.6630	130.2	0.351
20322−4521	−45 13874	RST 5470 AB	195286	1989.3069	144.0	0.210
20339+3515	HR 7866	WRH AB	196093	1988.6630	98.3	0.282
20347−6319	−63 04590	Hu 1615	195429	1989.3069	59.5	0.147
20393−1457	ADS 14099	Hu 200 AB	196662	1988.6631	115.0	0.273
20397+1556	ADS 14121	WCK Aa	196867	1988.6631	246.1	0.194
20406+2156	ADS 14148	A 2795	197075	1988.6631	251.8	0.236
20410+3905	HR 7922	McA 62	197226	1988.6631	100.8	0.051
20451+1244	ADS 14238	Bu 64 AB	197683	1988.6631	165.5	0.651
20474+3629	ADS 14296	STT 413 Aa,B	198183	1988.6631	14.3	0.865
20523+2008	ADS 14379	Ho 144	198810-1	1988.6631	348.5	0.352
20527−0859	HR 7990	McA 64	198743	1989.3123	135.9	0.060
20598+4732	ADS 14526	McA 65 Aa	200120	1988.6576	44.6	0.211
21032−2744	ADS 14565	See 435	200245	1988.6631	319.5	0.188
21091+2922	+28 4003	Cou 1332	—	1988.6631	18.1	0.210
21118+6000	ADS 14749	STF 2780 Aa,B	202214	1988.6576	215.9	1.053
21118+6000	ADS 14749	McA 67 Aa	202214	1988.6576	25.0	0.048
21145+1001	ADS 14773	STT 535 AB	202275	1988.6576	30.8	0.228
21214+1021	ADS 14893	A 617	203345	1988.6576	94.3	0.178
21253+2928	+28 4085	Cou 940	204051	1988.6632	274.1	0.325
21288+7034	HR 8238	β Cep Aa	205021	1988.6632	51.0	0.068
21315+4817	ADS 15058	A 771	205085	1988.6632	49.7	0.047
21329+4959	HR 8246	CHARA 102	205314	1988.6632	120.7	0.045
21425+4106	HR 8300	Kui 108	206644	1988.6632	11.4	0.201
21446+2539	ADS 15281	Bu 989 AB	206901	1988.6658	101.6	0.213
21498+3455	+34 4540	Cou 1484	207663	1988.6576	350.8	0.372
21502+1718	HR 8344	Cou 14	207652	1988.6576	68.9	0.218
21535−1019	HR 8355	Fin 358	208008	1988.6576	98.0	0.108
22139+3944	ADS 15758	McA 70 Ab	211073	1988.6576	10.2	0.465
22313−0633	HR 8581	CHARA 111	213429	1988.6659	72.7	0.090
22359+3938	ADS 16095	CHARA 112 Aa	214168	1988.6633	137.6	0.041
22375+1607	+15 4683	Hei 86	—	1988.6658	287.9	0.295
22383+4511	HR 8617	CHARA 114	214558	1988.6633	141.5	0.104
22394+8123	+80 0731	McA 72	215319	1988.6550	95.1	0.149
22402+3731	ADS 16164	Ho 188	214807	1988.6659	206.1	0.349
22408−0333	HR 8629	Kui 114	214810	1988.6577	126.8	0.291
22408+1432	ADS 16173	Ho 296 AB	214850	1988.6577	72.8	0.411
22426+2943	ADS 16199	Bu 710	215126	1988.6659	244.0	0.491

22431+4709	ADS 16214	STT 476 AB	215242	1988.6577	304°6	0″501
22431+4709	ADS 16214	Hu 91 BC	215242	1988.6577	40.0	0.061
22453+5128	ADS 16249	Hu 783	215590	1988.6659	185.8	0.199
22499+4834	ADS 16296	A 2398	——	1988.6659	160.2	0.234
22514+2624	ADS 16314	Ho 482 AB	216285	1988.6659	32.0	0.390
22535−1137	HR 8704	McA 73	216494	1988.6577	301.5	0.057
				1988.6633	306.6	0.057
				1989.3123	309.9	0.056
22570+2441	+23 4640	Cou 542 Aa	216963	1988.6659	225.5	0.115
22585+0922	ADS 16417	STT 536 AB	217166	1988.6577	346.9	0.182
22587+2611	+25 4852	Cou 543	——	1988.6659	117.7	0.239
22589+4617	ADS 16430	A 192	——	1988.6659	234.9	0.518
22592+1144	ADS 16428	STT 483	217232	1988.6577	312.1	0.553
23019+4219	HR 8762	McA 77 AB	217675	1988.6550	351.7	0.237
				1988.6577	351.6	0.236
				1988.6659	351.7	0.236
23020+4800	ADS 16457	A 194	217712	1988.6577	291.8	0.153
23024+1837	ADS 16463	Hu 398	217716	1988.6659	263.8	0.376
23024+6413	+63 1917	Mlr 69	217848	1988.6577	116.5	0.311
23026+4245	ADS 16467	Bu 1147 AB	217782	1988.6659	342.2	0.396
23052−0742	ADS 16497	A 417 AB	218060	1988.6577	50.1	0.210
23055+4643	ADS 16505	A 196	218196	1988.6659	316.1	0.476
23072+6049	ADS 16518	Bu 180 AB	218439	1988.6577	143.1	0.573
23078+6338	ADS 16530	Hu 994	218537	1988.6577	311.0	0.221
23101+5158	ADS 16559	Hu 1322	236058	1988.6659	124.6	0.472
23115+3813	ADS 16576	Ho 197 AB	218917	1988.6578	312.5	0.318
23122+4449	ADS 16586	A 197	219040	1988.6578	159.8	0.472
23126+0242	ADS 18591	A 2298	219018	1988.6605	83.0	0.096
23147+4116	ADS 16621	A 200	219334	1988.6578	80.4	0.558
23164+6408	ADS 16638	Bu 992	219633	1988.6577	38.6	0.277
23168+6148	ADS 16645	Bu 853 AB	——	1988.6577	231.1	0.561
23176+1819	ADS 16650	Hu 400	219675	1988.6605	119.9	0.345
23191−1327	ADS 16672	McA 74 Aa	219834	1988.6605	136.0	0.190
23198+4243	+41 4751	Cou 1646	——	1988.6578	51.7:	0.169:
23199+2845	+27 4530	Cou 439	219963	1988.6660	221.6	0.214
23199+3444	+33 4690	Cou 742	219982	1988.6659	28.5	0.264
23209+1643	+15 4809	Hei 88	220077	1988.6660	217.8	0.247
23226−1503	ADS 16708	Hu 295	220278	1988.6605	118.1	0.211
23239+3456	+34 4915	Cou 1346	——	1988.6659	84.2	0.228
23241+5732	ADS 16731	STT 495	220562	1988.6578	120.4	0.317
23259+2742	ADS 16746	Ho 489 AB	220723	1988.6660	227.0	0.544
23266+2342	+22 4835	Cou 338	220794	1988.6605	39.6	0.102
23268+5434	ADS 16760	A 1485	220869	1988.6578	212.2	0.565
23269+6414	+63 1995	Mlr 72	220907	1988.6577	161.7	0.183
23288+4225	+41 4791	Cou 1847	221102	1988.6578	29.9	0.086
23305+3050	ADS 16800	Bu 1266 AB	221264	1988.6605	73.2	0.258
23307+6420	ADS 16806	Bu 774	221333	1988.6577	338.1	0.623
23322+1942	+18 5163	Cou 340	——	1988.6605	58.8	0.283
23322+0705	ADS 16819	Hu 298	221445	1988.6605	207.5	0.111
23339+2342	+22 4860	Cou 144	——	1988.6605	54.8	0.335
23340+3120	ADS 16836	Bu 720	221673	1988.6604	265.9	0.527
23363−0707	ADS 16858	Bu 721 AB	221925	1988.6605	135.4	0.251
23374+0737	ADS 16873	Fox 102 AB	222068	1988.6660	316.9	0.237
23375+4426	ADS 16877	STT 500 AB	222109	1988.6578	0.4	0.492
23382+5514	ADS 16886	A 1493	222186	1988.6578	359.0	0.143
23392+4543	ADS 16904	A 643 AB	222326	1988.6578	156.3	0.218
23392+4543	ADS 16904	CHARA 149 Aa	222326	1986.8914	53.5	0.048
				1988.6578	31.0	0.048
23412+4613	+45 4301	Mlr 4	222516	1988.6578	19.9	0.064
23425+5436	ADS 16941	A 1495	222672	1988.6578	181.1	0.489
23460+4625	HR 9003	McA 75 Aab	223047	1988.6550	102°6	0″301
23485+3608	+35 5106	Cou 944	——	1988.6578	97.1	0.192
23485+3617	ADS 17019	B 2547 AB	223331	1988.6578	2.9	0.231
23486+6453	ADS 17020	STT 507 AB	223358	1988.6606	308.7	0.725
23492+1915	+18 5223	Cou 343	223402	1988.6606	116.3	0.200
23498+2740	ADS 17030	A 424	223486	1988.6550	116.2	0.168
23502+1940	+18 5226	Cou 344	223523	1988.6606	18.1	0.196
23506+4705	ADS 17039	A 793	——	1988.6606	127.9:	0.131:
23516+4205	ADS 17050	STT 510 AB	223672	1988.6550	305.8	0.553
23517−0637	ADS 17052	A 2700	223638	1988.6605	243.5:	0.125:
23529−0313	HR 9041	Fin 359	223825	1988.6633	281.5	0.042
23545+4408	+43 4571	Cou 1497	——	1988.6606	29.5	0.376
23557+4318	+42 4792	Cou 1498	224167	1988.6606	45.7:	0.159:
23561+2520	ADS 17105	A 426	224217	1988.6606	316.1	0.377
23561+2327	ADS 17104	Hu 500	224219	1988.6606	88.3	0.173
23568+0443	ADS 17111	A 2100	224315	1988.6605	127.9	0.093
23578+2508	HR 9064	McA 76	224427	1988.6606	63.4	0.136
23586−1408	−14 6588	RST 4136 AB	224512	1988.6605	19.8	0.192
23594+5441	ADS 17151	A 1498	224646-7	1988.6606	85.0	0.390

THE CHARA ARRAY III.

ANDERSON MESA, ARIZONA, AS A SITE FOR AN OPTICAL ARRAY

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ABSTRACT

From measurements of cloudcover, seeing profiles, and microthermal properties, Anderson Mesa, near Flagstaff, Arizona, has been evaluated as a potential site for an optical interferometric array. From satellite cloud measurements, northern Arizona was found to have experienced [illegible] skies than those of southern Arizona and New Mexico during 1984–87, with an expected lower frequency and extent of monsoon related activity. Using a simple and inexpensive system for measuring instantaneous FWHM of stellar images, the seeing at Anderson Mesa was determined to be well represented by the statistics at the nearby USNO Flagstaff Station from which a median seeing of 1.2 arcsec FWHM has been reported. Limited microthermal measurements indicate that Anderson Mesa is rather similar to Mt. Graham where tree cover plays a significant role. Anderson Mesa is concluded to be a highly suitable site for an optical array.

Key words: optical interferometry–site selection

1. Introduction

The feasibility of a long-baseline, multiple-telescope interferometric array operating at optical wavelengths has been under investigation at GSU/CHARA since early 1986. The CHARA Array in its final design concept form has been described by McAlister (1989a,b) as well as in the first paper in this series (McAlister *et al.* 1990). An important aspect of this study has been the selection of a site at which the proposed array would be constructed. Criteria for site selection were terrain, meteorology, darkness, geology, logistics, and seeing. Several sites in the southwestern U.S. have been studied in the context of the CHARA Array. The necessity that a site provide extensive two-dimensional placement of array elements eliminates many developed sites from consideration. Logistical considerations weighed against several other sites as well.

We assigned a relatively low weight to the criterion of darkness. At a dark site, the background visual magnitude per square arcsec is typically m_v ~22, which is 8 magnitudes dimmer than the estimated ultimate limiting magnitude of m_v ~14 for the interferometer. There is, therefore, some margin of safety for this criterion. Moreover, a recent estimate (Garstang 1989) has shown that the light pollution in V at Anderson Mesa will be only 0.24 and 0.30 mag. above background at the zenith in 1990 and 2000 respectively, and this model does not include any light pollution ordinance action in Flagstaff.

Seeing conditions affect interferometry in several ways. Firstly, in pupil plane interferometry poor seeing requires a greater number of detector elements (or optical fibers, etc.) to adequately sample the fringe pattern and avoid loss of measured visibility. Because the number of detector elements is proportional to r_o^{-2} where r_o is the atmospheric transverse coherence length, or Fried parameter (see the paper by Coulman in Millis *et al.* 1987) and because more elements means more computing capability and data storage, it is desireable to have as good seeing as possible.

Secondly, the signal to noise ratio (SNR) and the limiting magnitude are dependent on seeing (Roddier and Lena 1984, Humphreys *et al.* 1984), where the limiting irradiance $L \sim r_o \tau \Delta\lambda$ where τ is the atmospheric redistribution time and $\Delta\lambda$ is the bandwidth. If the frame time and bandwidth could be changed to take advantage of good seeing then $L \sim r_o^{17/6}$, if these are fixed for design reasons, then $L \sim r_o$. Thus an improvement in seeing from r_o = 10 cm to 15 cm could improve the limiting magnitude by 0.45 to 1.25 mag. Note that if the seeing deteriorates so that τ is less than the detector frame time, the facility must shut down, as is the case if r_o is too small to be well resolved by the detector.

Finally, good seeing allows a better correction of wavefront if a compensated imaging system with a small number of actuators ($\leq$15) is used (McAlister 1989b). Therefore, for these general reasons and for the CHARA Array design in particular, it is desireable to have a high

percentage of seeing with $r_0 \geq 7$ cm or better than ~1.4 arcsec.

A low cloudcover is a requirement perhaps so obvious that recent consideration of it have been relatively neglected. In a conference dealing with astronomical site selction held in Flagstaff (Millis *et al.* 1987), consideration of cloudcover occupied less than 5% of the papers given. Nevertheless, because the astronomical productivity of a site is at least proportional to its cloudcover, this should be given a significant weight in site selection.

In this paper, we report a comparative analysis of relative cloudcover at these sites and new measurements of seeing conditions from Anderson Mesa, near Flagstaff, Arizona, the site proposed for the CHARA Array.

2. Comparative Cloudcover Analysis

The five sites listed in Table 1 were examined as potential locations sites for the CHARA Array. Although it does not possess suitable terrain, Kitt Peak was included for comparison purposes. Satellite weather data were obtained from the National Climatic Data Center in Asheville, North Carolina. These data include the interval January 1984 through September 1987, and describe the region within longitude 98° to 114°W and latitude 26° to 40°N. Weather maps were encoded in gray–level scales according to relative cloudcover averaged with respect to year, month, and hour. These weather data include 45 months of four measurements per night (at UT = 0, 3, 6 and 9 hour). A satellite map distortion correction routine and a data smoothing routine have been applied in this study. The locations of the five sites in Table 1 are shown as plus signs in the resulting maps and state boundaries are also drawn. On each of the weather maps shown in Figures 1 through 5, the cloudiness levels are shown on the top-left-hand side by 10% steps decreasing from top to bottom (top white means 0% cloudy and bottom black means 100% cloudy, respectively).

The last general mapping of cloudcover in the southwest for astronomical use was done by Smith and McCrosky (SM) (1954), based on data from twenty weather stations. In comparing our results with SM, we note the following:

1.) The most prominent region in terms of low cloudcover in these maps is the region just to the east of Flagstaff including the Painted Desert area. There is only a slight indication of this feature on SM's map (their Fig. 12).

2.) The clearest region of SM's map is the desert area near Yuma. In our data, the western portion of this region (Yuma itself is truncated) shows good, but not outstanding cloudcover conditions.

3.) The new data do not show the "peninsula" of clear weather up the Rio Grande valley noted by SM.

4.) Both the older and newer data sets qualitatively agree on the characteristics of the summer monsoon seasons.

5.) Both sets also agree on the general cloudiness associated with the mountains along the Continental Divide. Our maps also extend this feature into Mexico.

The differences between our maps and the SM map no doubt largely result from natural, short–term changes in climate. There must also be relative differences in airport *versus* satellite measurements of cloudcover. Satellite data has the advantage of being uniform in its sensitivity to relative cloudcover and is immune to the observer–to–observer variations inherent in airport reports.

An annual average of the cloudcover statistics is shown in Figure 6 and indicates that Anderson Mesa was the clearest of the five sites during the data interval. The clearest months at Anderson Mesa are January, May, September, and October with average cloudcover lower than 20%. In Figure 1, the year–average weather maps for 1984, 1985, and 1986 near midnight (UT = 7:30) are shown with the entire 45–month period included in the map on the lower right-hand side. Although the three year-average maps show variations from year to year, Anderson Mesa still has the lowest year-average percentage cloudcover within the specific confines of the 1984-1987 data set. Figure 2 is an example of average change at progressive night-time hours (UT = 0, 3, 6, and 9 hours) for the 1986 data set. The Anderson Mesa area shows a distinct improvement into the night–time hours. On the month-average maps, which are not shown here, the improvement of cloudcover from early evening to midnight is similar to that indicated in Figure 2. Figures 3, 4, and 5 present month-average maps (at UT = 7:30) from January through December. On these figures, Kitt Peak and the two New Mexico sites show particularly strong monsoon (July and August) related cloudiness.

3. Seeing Measurements

3.1 *Equipment*

The CHARA/Lowell seeing monitor system used on Anderson Mesa is a portable and inexpensive device designed by authors White and Bagnuolo. The detector is a standard high-resolution miniature TV camera manufactured by Pulnix Corporation (their model TM-540/R) and is based upon a Sony O18-L 510x492 interline transfer CCD chip with a format of 17 x 13 μm pixels. This camera is mounted on a housing incorporating a Strömgren y filter and attached to an f/11, 14-in aperture Celestron telescope. The composite video signal is digitized and processed by an Imaging Technology PC Vision Plus frame grabber installed in an IBM/AT–type computer.

A Hartman mask and a focus mechanism designed by White, as shown in Figures 7 and 8, were used to determine precise focus. The Hartman mask has two 4-in diameter holes with 8 inchs of separation between their centers. The focus mechanism incorporates a micrometer device attached to the telescope eyepiece tube. This device is initially set to within ± 3 mm of the focal plane. Then, with the Hartman mask attached to the entrance aperture of the telescope, 60 frames of double-spot images (aligned in the Y–direction) at micrometer positions inside and outside of focus are recorded and analyzed to determine the precise focus.

3.2 *Data Acquisiton and Processing*

Each seeing measurement consisted of a series of 60 digitized 32x32–pixel images of a bright star within 20° of the zenith obtained at the standard video frame rate of 30 sec^{-1}. The X,Y image profiles, their full width at half-maxima (FWHM), and the image centroids were determined on-line.

The FWHM were calculated by a simple raw-data summation algorithm method in order to obtain high speed during the data acquisition period. Absolute image motion was also calculated by using a simple first-moment centroid routine on-line. Precise FWHM of X and Y profiles and image centroid motions were later calculated from disk files by using a 1–dimensional Gaussian profile fitting routine after the detector linearity calibration was applied to each frame. There were 60 X and Y profiles in each two–second measurement with 15 pixels of the raw data across the image center selected for the Gaussian fitting. The mean FWHM of the 60 single profiles in each measurement was calculated as representative of the seeing at that particular moment. The mean FWHM of the 60 X and Y profiles with centroid motion correction was also calculated for comparison with the mean FWHM. This provided a check

on abnormal vibrational effects as well as monitoring low-frequency image motion.

The above procedures revealed that the X profiles were about 0.6 arcsec broader than the Y profiles. This was recognized as being due to the chip geometry in which the interline vertical register separates the pixels in the X direction. This can be corrected statistically to some degree, however, the X direction was oriented parallel to the celestial equator so that the X profiles are also more affected by any telescope drive-induced errors. For these reasons, we chose to base the final seeing measurements only on the Y profile data.

3.3 *Calibration*

The plate scale calibration was determined from double star observations to be 0.80 and 0.64 arcsec per pixel in the X and Y directions, respectively. The intensity calibration for detector non-linearity used a camera lens with an adjustable iris (from f/2.7 to f/16) to image a small target at a distance of 6.7 m. The intensities of an effective point source and extended source were recorded as a function of the f/number. The results of these measurements are shown in Figure 9 and are characterized by a small toe in response, followed by a roughly linear region extending to about 80 counts. At brigher intensities, the response roughly followed the square-root of the intensity. In Figure 10, examples of data obtained under good and poor seeing conditions are shown before and after applying the linearity correction.

Because the Pulnix CCD camera automatic gain control (AGC) and standard gamma (= 0.45) circuit were enabled during the observations, calibration tests using a LED light source were carried out in the CHARA Lab in order to duplicate the high contrast situation presented by a bright source on a dark background. A gamma <1 has the advantage of expanding the dynamic range at a loss of contrast and thus enhances the ability to measure the peaks of a Gaussian profile. For testing, the electronics of the Pulnix camera were modified to provide a six-step manual gain control circuit. The tests were done at a laboratory temperature of 70°F as well as at a temperature of 32°F similar to that encountered during the obervations on Anderson Mesa. The results were essentially the same as those from the first linearity check, and the reponse curve at freezing temperature showed no significant differences from that obtained at room temperature.

3.4 *Results of Seeing Measurements*

In order to ascertain the long-term seeing characteristics at Anderson Mesa, short-term quantitative measurements were related to the existing results of the long-term quantitative seeing measurements at the U.S. Naval Observatory's Flagstaff Station site some 13 miles from

Anderson Mesa. The process was to compare measurements with the CHARA/Lowell system at Anderson Mesa on nights when seeing was also being measured at the USNO with their standard CCD procedures and to compare simultaneous measurements at the same site.

A comparison of seeing data from the two sites for the night of [illegible] May, 1988 is shown in Figure 11. This comparison shows that the seeing on Anderson Mesa was approximately 0.3 arcsec poorer than at the USNO at this particular time. The observing log notes that the wind was higher than normal on that night at Anderson Mesa, and it is possible that tree-induced turbulence as well as wind generated instrument shake, may account for some difference in average seeing in Figure 11. The seeing monitor system, with an entrance aperture only 2 m above the ground, was set up for practical reasons inside the fenced area surrounding the 72-in and 42-in telescope domes at Anderson Mesa near a small stand of trees. It thus seems likely that the difference in measured seeing at the two sites may be partly attributable to the less than ideal location of the CHARA/Lowell system on Anderson Mesa. There are no trees in the immediate vicinity of the USNO 61-in telescope dome. We thus conclude that very localized conditions may possibly account for some modest systematic difference in the seeing statistics for the two Flagstaff locations, but the general seeing characteristics at Anderson Mesa are very similar to the USNO site. It is important to note that the part of Anderson Mesa where the CHARA Array would be located has a much lower density of trees than the area immediately surrounding the Perkins telescope.

During 10 - 13 June, 1988, the CHARA/Lowell seeing monitor was placed about 30 m west of the USNO 61-inch telescope dome in order to measure seeing simultaneously with the 61-inch telescope where seeing data are routinely acquired as a part of the USNO astrometry programs. On the night of 10 June, only knife-edge measurements rather than direct CCD imagery were being performed on the USNO telescope. In Figure 12 is shown the correlation of seeing measurements of the two systems. An empirical/theoretical factor of 3.5, provided by D. Monet and C. Dahn, was adopted to correct the USNO knife-edge measurements to FWHM values. The average inferred seeing disk profile measured from the USNO knife-edge data is about 0.35 arcsec larger than the average seeing from the CHARA/Lowell system on this particular night.

On the nights of 11 and 13 June, the 12^{th} having been cloudy, additional simultaneous measurements were obtained, but in these instances, the USNO measures were obtained with a CCD camera. The FWHM seeing measurements from the two systems throughout these two nights are plotted in Figure 13. The apparent large discrepancy around 8.0 hours on 13 June coincided with an increased wind speed outside the 61-inch dome and was clearly due to wind shake. The discrepancy around UT=5:30 is attributed to a focus drift caused from the steep temperature gradient during the early night hours. The CHARA/Lowell measures before 7.5 hours UT on both nights were obtained using a Strömgren y filter, those after that

time incorporated a Johnson B filter. There is no evidence for any systematic difference in the two systems in excess of 0.1 arcsec.

Figure 14 presents the histogram of 161 measurements using the CHARA/Lowell system during three nights at the USNO site from which the mean seeing was 1.20 arcsec with a median value of 1.04 arcsec. The histogram shown in Figure 15 summarizes the 236 measurements from the USNO 61-inch telescope CCD camera on 6 nights with mean and median seeing of 1.04 and 1.00 arcsec. Those data were obtained during the time when the CHARA/Lowell seeing monitor was active on Anderson Mesa. Results from 364 image profile measurements obtained at Anderson Mesa on 21 nights during May and June 1988 are shown in Figure 16. The mean value of the seeing profile FWHM is 1.24 arcsec, and the median is 1.18 arcsec. Finally, the long-term seeing statistics from the USNO program are shown in Figure 17. The 70 nights over which these 1,003 measurements were obtained from the USNO CCD camera extend from April 1986 through July 1987. The mean FWHM of image profiles in this sample is 1.34 arcsec and the median is 1.20 arcsec.

The long-term USNO statistics are biased in the poor seeing tail due to the practice instituted many years ago at the USNO of not taking astrometric data or seeing measurments when the seeing is worse than 2 arcsec. But no such bias against poor seeing is presented in the CHARA/Lowell system measurements except for the general bias resulting from the limited time sample of data, i.e. 21 nights during May and June 1988. From the above discussion we conclude that the seeing described by the USNO CCD measurements must be generally representative of Anderson Mesa as well.

This result contradicts the conclusion by Walker (1971) that Flagstaff is a poor site in the category of seeing. Walker's conclusion was based upon Polaris trail measurements using a 6-inch refracting telescope mounted upon an existing pier outside the dome of the USNO 40-inch telescope during 1966–68. Those data indicated that the seeing was typically poorer than 2.0 arcsec. A period of poor seeing was experienced during 1971–74 (private communication from F. Vrba) and may have resulted from the placement of the jetstream. Walker's results may also have been systematically affected due to the fact that Walker's seeing telescope looked very nearly directly over the heated and uninsulated office building for the 40-inch Telescope.

4. Microthermal Activity Measurement

An 18-m high tower is situated between the 72-in and 42-in telescope domes at Anderson Mesa. Three microthermal probe pairs were mounted at 18.3, 12.4, and 7.1 m above the ground to measure the vertical structure of microthermal activity. The microthermal probes were developed at NOAO (Forbes *et al.*, 1988) and consisted of 25 μm nickel ballast wire wound on

a nylon screw frame, protected by an easily removed screen cage. At each level, there were two probes separated by about 1 m and connected to a bridge amplifier electronic circuit.

Data from the three levels were collected and stored in a Campbell Scientific CR 21 data logger at the first minute of every hour. The data system is equipped with a rechargeable battery and could thus automaticlly record data in RAM for about two weeks. The collected data were reduced to C_T^2 (rms) for each observation. Calibration was obtained from the energy spectra and the resultant power spectra were integrated. During June and July 1988, a two 9-day series of microthermal measurements and ground temperature measurements were collected and later analyzed at NOAO. The microthermal data has been combined in Tables 2 and 3 using nightly averages from 8 p.m. to 4 a.m. for each level as being representative of the site.

The results of the microthermal measurements on Anderson Mesa, indicated by :: symbol, are shown in Figure 18 as a plot of the temperature structure parameter C_T^2 *versus* elevation. For comparison, the NOAO results for Mauna Kea and Mt. Graham are also shown. Although the Anderson Mesa microthermal data are, at present, very limited, one can tentatively conclude that the Flagstaff location is not very different from Mt. Graham, probably due to the similarity of tree cover. We plan to see if conditions are improved at the sparsely wooded center of the array, particularly after a number of trees have been cleared during site preparation.

5. CONCLUSION

From the analysis of the satellite cloudcover data during the time interval from January 1984 to September 1987, the Flagstaff area is seen to compare very favorably with other possible locations in the southwest. Such a clear distinction does not appear in the earlier study by Smith and McCrosky (1954) for the period 1939–46 except for the relatively small impact of the summer monsoons on north Arizona compared to more southerly sites. The lack of precise similarity between our study and the SM study can easily be explained in terms of natural weather pattern variations. Furthermore, we recognize that by the time an array might be constructed in northern Arizona, the changes could completely eliminate the cloudcover advantage we have found.

The results obtained with the CHARA/Lowell seeing monitor show a good correlation to the long-term seeing measurements made at the USNO 61-inch telescope, and we conclude that the USNO seeing history is representative of Anderson Mesa as well. An interferometric array on Anderson Mesa could thus be expected to encounter 1.1 to 1.2 arcsec seeing during 50% of the clear hours and seeing poorer than 2.0 arcsec during another 30% of clear hours. Such seeing conditions qualify Anderson Mesa as a potential site for an interferometric array.

Better seeing may be found only at much higher elevations for continental sites or for coastal or island sites where terrain and logistics may have negative impacts upon site selection.

Further testing is planned for Anderson Mesa in which very localized effects of tree cover, elevation, and proximity to the steep western slope of the Mesa will be investigated.

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TABLE 1

Sites Considered for the CHARA Array

Potential Site	Longitude	Latitude	Altitude
Anderson Mesa, Arizona	111.54 W	35.10 N	7,211 ft
Kitt Peak, Arizona	111.60 W	31.96 N	6,667 ft
Blue Mesa, New Mexico	107.17 W	32.49 N	6,644 ft
Sunspot, New Mexico	105.82 W	32.79 N	9,200 ft
Flat Top, Texas	104.02 W	30.67 N	6,660 ft

TABLE 2

Microthermal Data (ΔT in °C) for June 1988

June date	top (avg)	mid (avg)	bot (avg)	top (min)	mid (min)	bot (min)	top (max)	mid (max)	bot (max)
7	2.12	1.16	1.03	0.64	0.33	0.34	5.97	3.77	3.63
8	2.07	1.10	1.01	0.40	0.21	0.21	7.73	4.48	4.29
9	1.88	1.01	0.93	0.45	0.23	0.21	6.29	4.49	3.83
10	1.66	0.89	1.16	0.43	0.25	0.33	6.25	3.55	4.21
11	1.98	0.94	1.02	0.51	0.23	0.29	6.86	4.11	3.86
12	1.38	0.76	0.66	0.34	0.17	0.16	5.23	3.44	3.03
13	1.02	0.64	0.68	0.26	0.16	0.16	4.32	2.19	2.51
14	1.69	0.92	0.84	0.37	0.18	0.18	6.57	2.93	3.65
15	1.49	0.80	0.78	0.36	0.20	0.20	5.55	2.68	3.66

TABLE 3

Microthermal Data (ΔT in °C) for July 1988

July date	top (avg)	mid (avg)	bot (avg)	top (min)	mid (min)	bot (min)	top (max)	mid (max)	bot (max)
5	1.09	0.42	0.79	0.28	0.34	0.16	3.74	0.51	3.10
6	1.88	0.36	0.46	0.18	0.04	0.08	5.95	1.85	2.04
7	1.02	0.64	0.70	0.25	0.16	0.14	3.72	2.28	2.59
8	1.21	0.74	0.89	0.27	0.21	0.21	3.94	2.51	3.28
9	1.46	0.90	0.91	0.42	0.24	0.28	5.09	3.06	2.98
10	1.27	0.76	0.96	0.23	0.18	0.23	4.37	3.11	3.74
11	1.33	0.87	0.96	0.33	0.24	0.23	4.29	2.89	3.42
12	0.98	0.56	0.58	0.18	0.11	0.13	4.44	2.30	2.36
13	1.17	0.52	0.64	0.23	0.10	0.12	4.37	2.25	2.85

FIGURE CAPTIONS

FIG 1—The year-average weather maps for 1984, 1985, and 1986 near midnight (UT = 7:30) with the entire 45-mo period included in the map on the lower right-hand side.

FIG 2—An example of average change at progressive night-time hours (UT = 0, 3, 6, and 9 hours) for the 1986 data set.

FIG 3—The month-average maps at UT = 7:30 from January through April.

FIG 4—The month-average maps at UT = 7:30 from May through August.

FIG 5—The month-average maps at UT = 7:30 from September through December.

FIG 6—Comparative cloudcover percentages are shown for five sites in the southwestern U.S. The curves are based upon satellite measurements obtained from the National Climatic Data Center and indicate that the Flagstaff site was the most favorable location during the period 1984–87 covered by the data sample.

FIG 7—The schematic diagrams of the focusing mechanism and the data collection path of the seeing monitor are shown.

FIG 8—Photographs of the Hartman mask and the focusing mechanism on the seeing monitor are shown.

FIG 9—The laboratory measured linearity correction relation for the seeing monitor system is shown as determined by a uniformly illuminated source and by a point source are shown.

FIG 10—Examples of measured profiles in the Y-direction before and after the non-linearity correction are shown under good and poor seeing conditions.

FIG 11—Image profiles as measured at the USNO site from within the 61-in telescope dome the standard USNO CCD procedures (shown as open squares) and at the Anderson Mesa site between the 72-in and 42-in domes using the CHARA/Lowell system (shown as filled squares) are presented for the night of 15 May 1988. A higher than normal wind on this night is a possible reason for the 0.3-arcsec poorer seeing on Anderson Mesa.

FIG 12—Image profiles as measured at the USNO site from within the 61-in telescope using the USNO knife-edge procedures (shown as open squares) and from outside the dome using the CHARA/Lowell system (filled squares) are presented for the night of 10 June 1988. A factor of 3.5 is adopted to convert the USNO knife-edge measurements to FWHM values.

FIG 13—Image profiles as measured at the USNO Flagstaff site

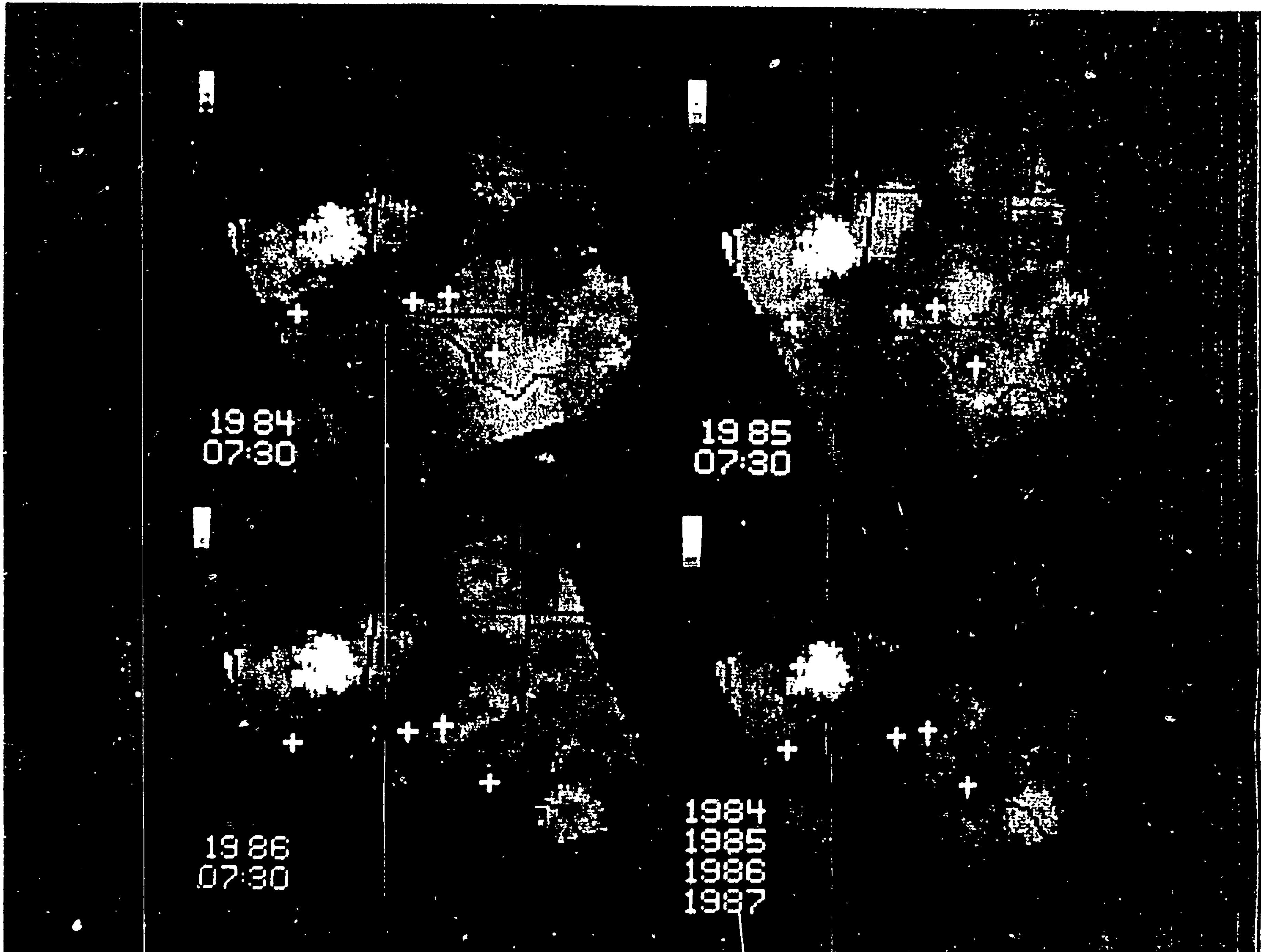
FIG 14—The histogram of the seeing measurements obtained at the USNO Flagstaff Station with the CHARA/Lowell seeing monitoring system during the nights of 9, 10, 11, and 13 June 1988 is shown.

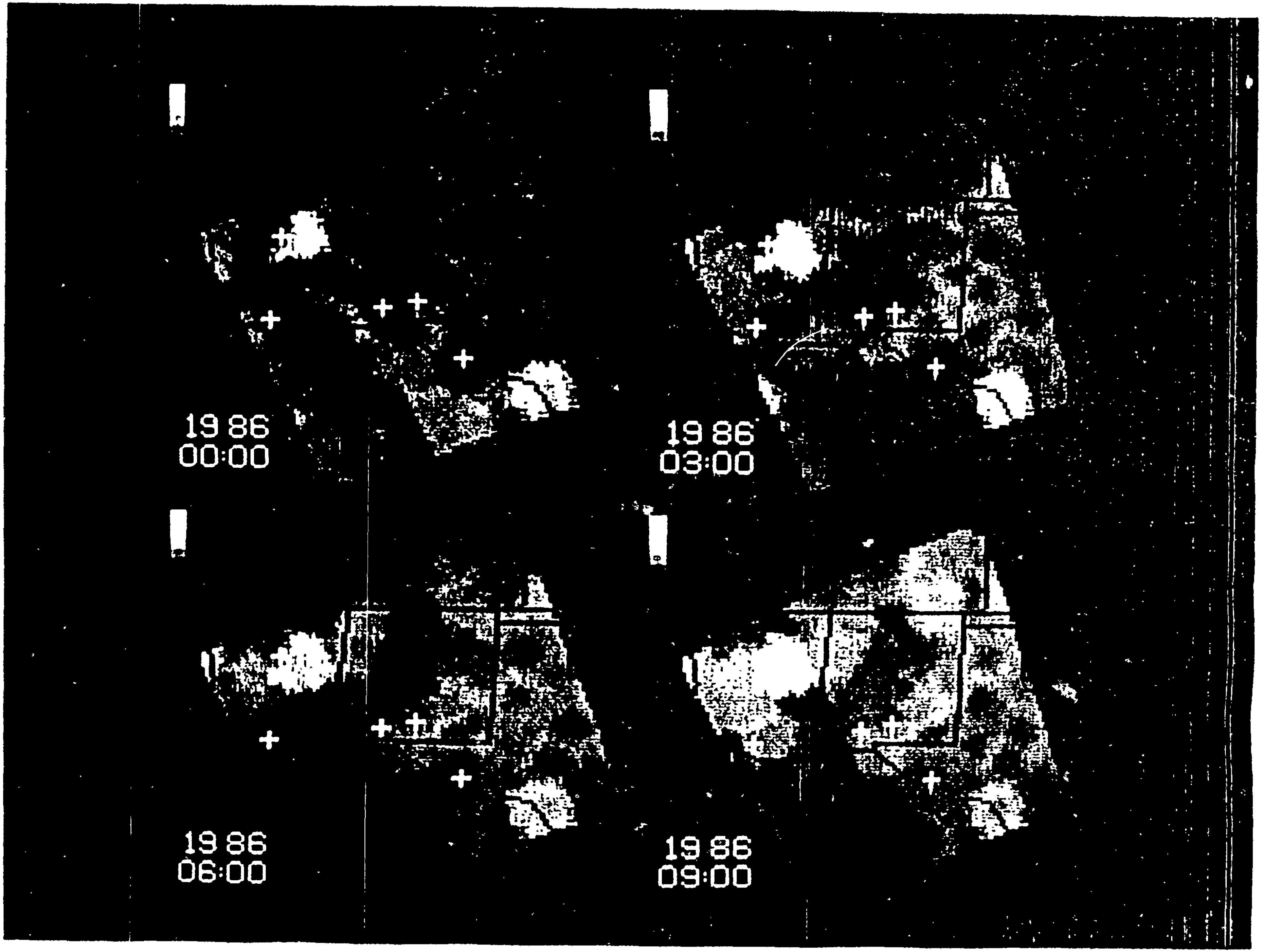
FIG 15—The histogram of the seeing measurements obtained at the USNO Flagstaff Station with the 61-in telescope CCD system during the nights of 12–15 May and 11 and 13 June 1988 is shown.

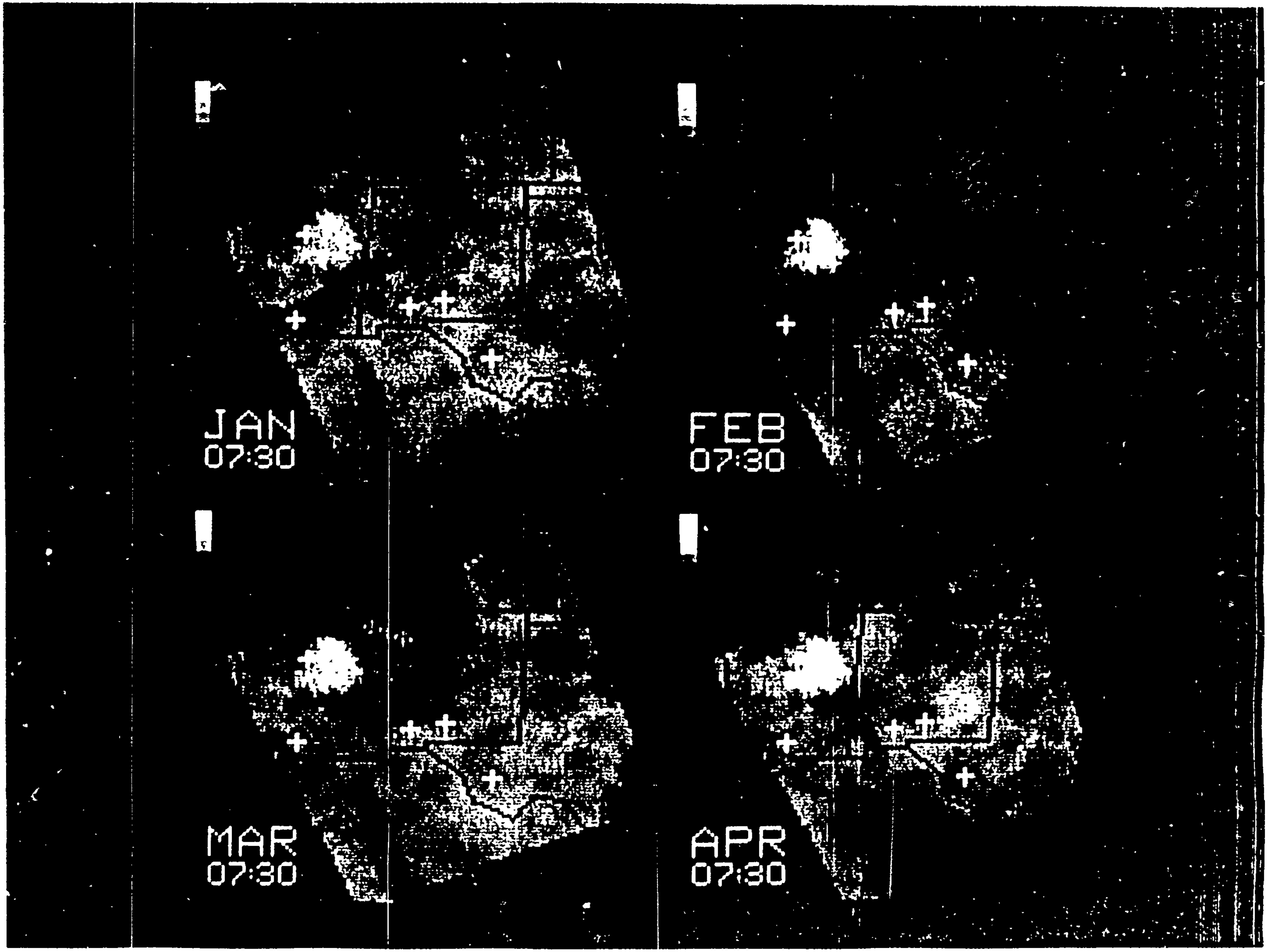
FIG 16—The histogram of the seeing measurements obtained on Anderson Mesa with the CHARA/Lowell seeing monitoring system during April–June 1988 is shown.

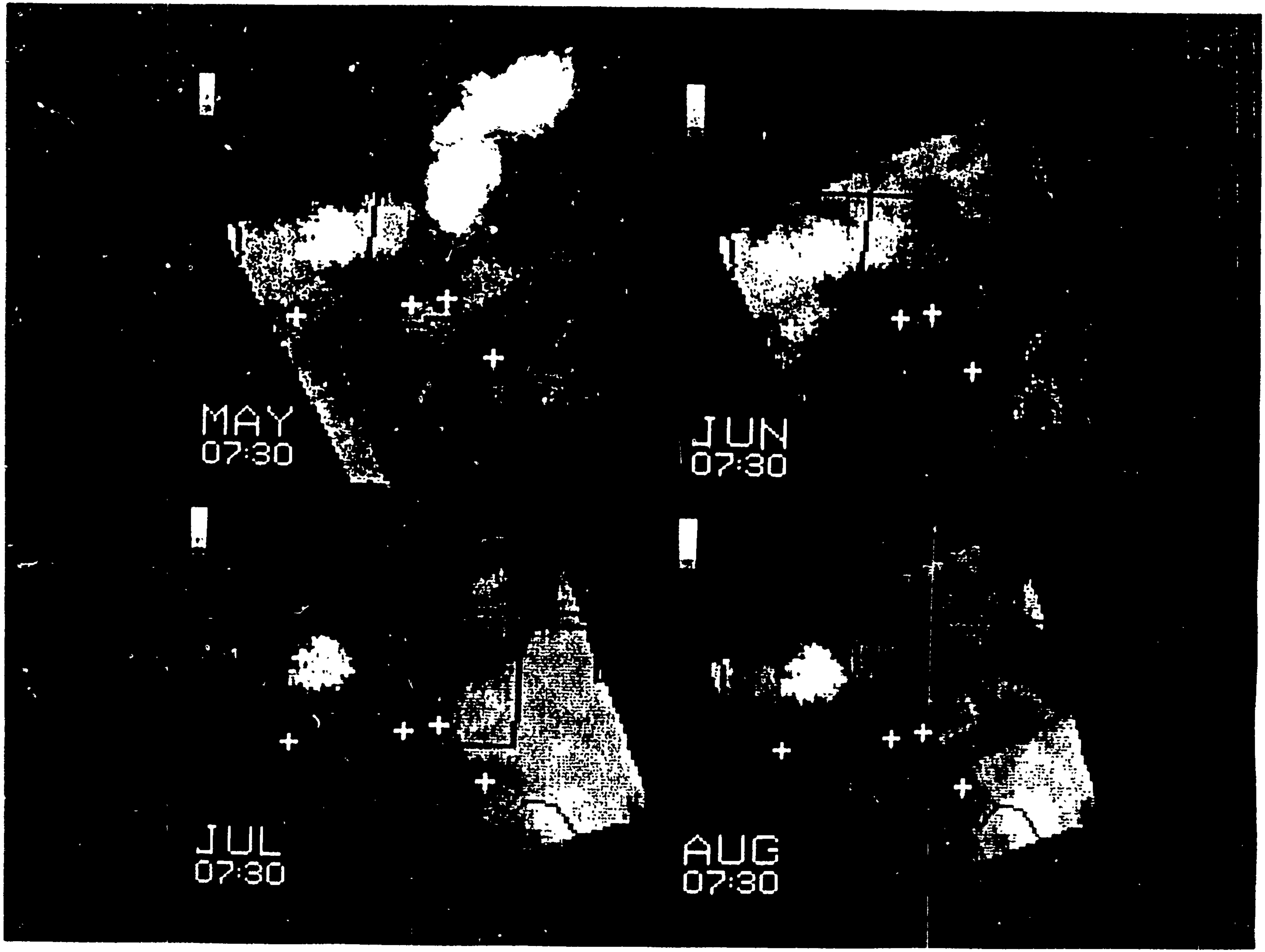
FIG 17—The histogram of the seeing measurements obtained at the USNO Flagstaff Station with the 61-in telescope CCD system on 70 nights during April 1986 through July 1987 is shown.

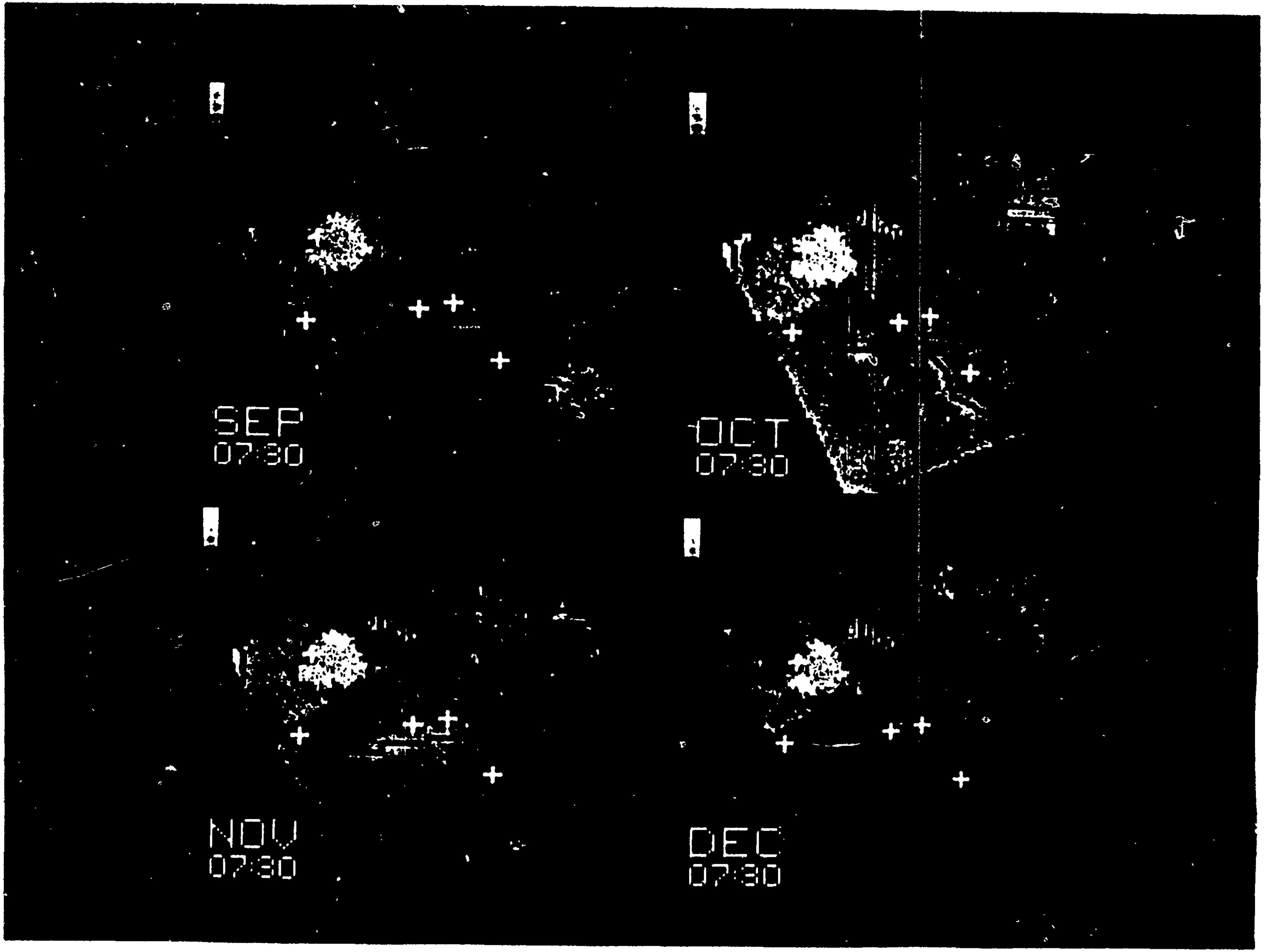
FIG 18—Three average microthermal measurements reduced to the temperature structure constant are shown (as circled dots) for Anderson Mesa as a function of height above ground level. For comparison, the NOAO results for Mt. Graham and Mauna Kea are shown and indicate a similarity between Anderson Mesa and Mt. Graham.

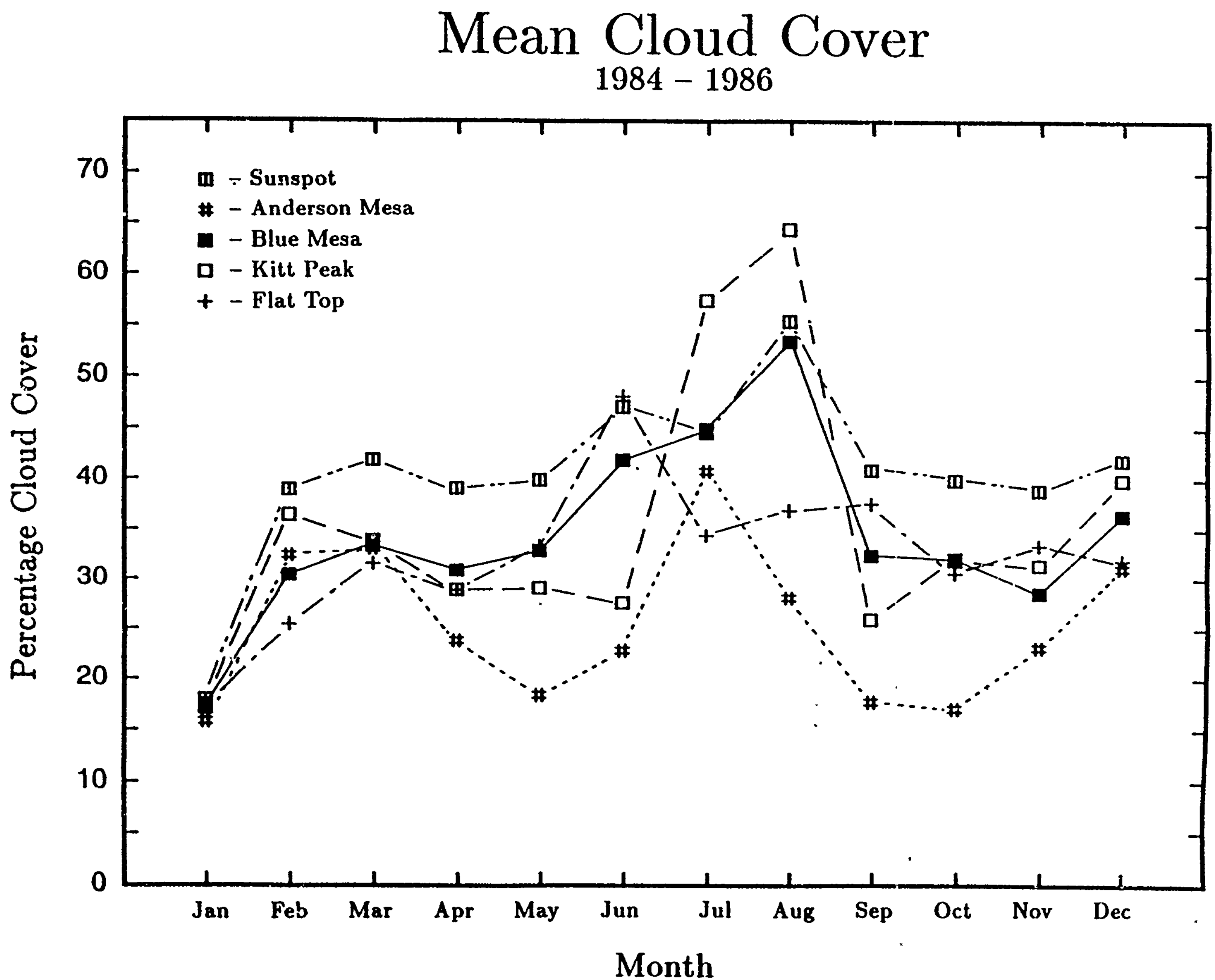

1984
07:30
1985
07:30
1986
07:30
1984
1985
1986
1987

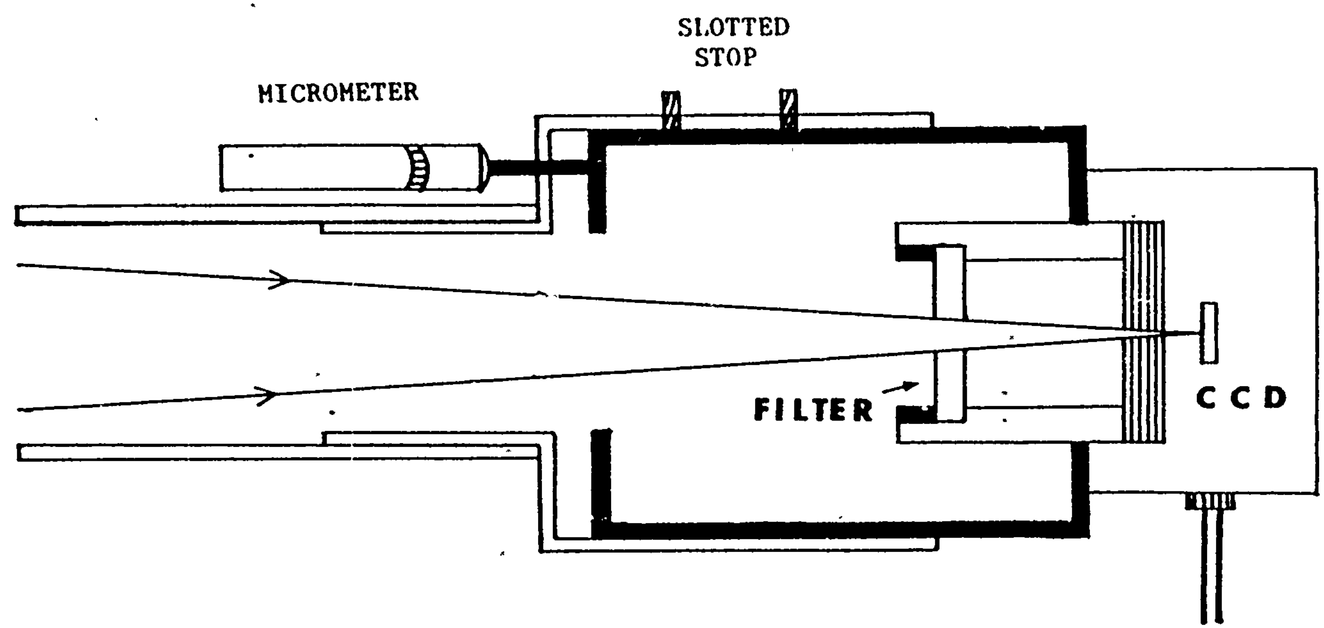

19 86
00:00
19 86
03:00
19 86
06:00
19 86
09:00

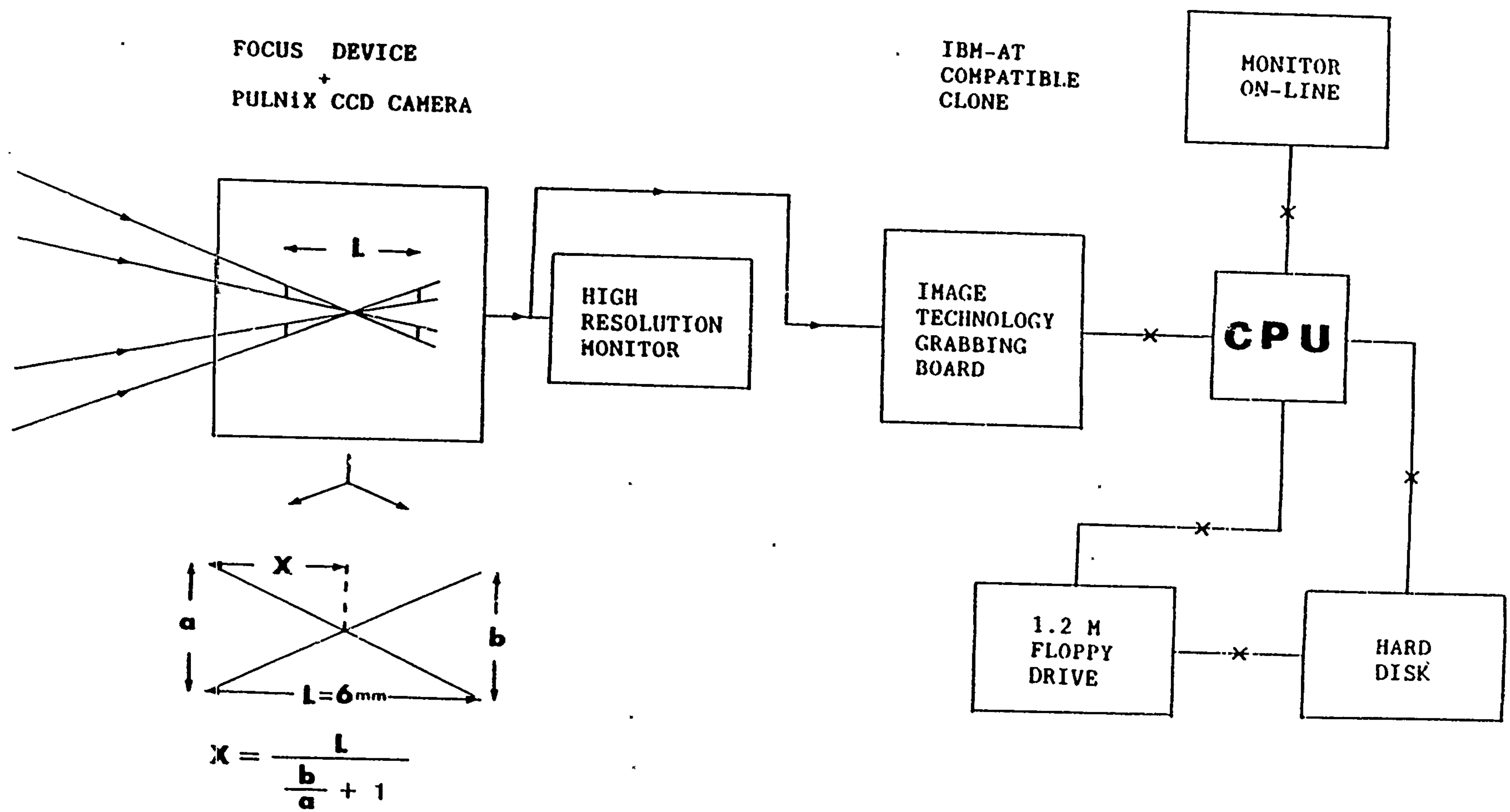

JAN
07:30
FEB
07:30
MAR
07:30
APR
07:30


MAY
07:30
JUN
07:30
JUL
07:30
AUG
07:30

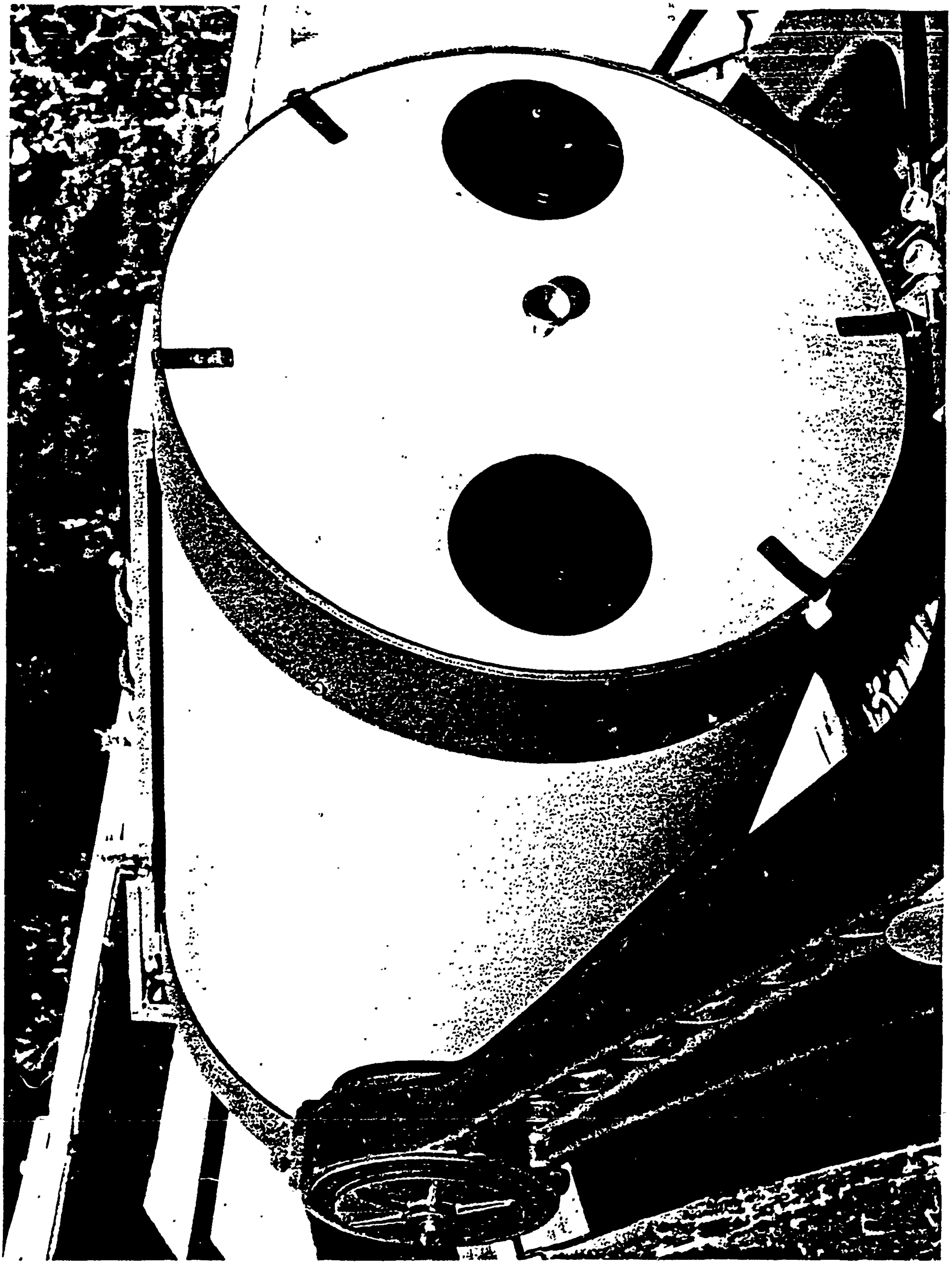

SEP
07:30
OCT
07:30
NOV
07:30
DEC
07:30

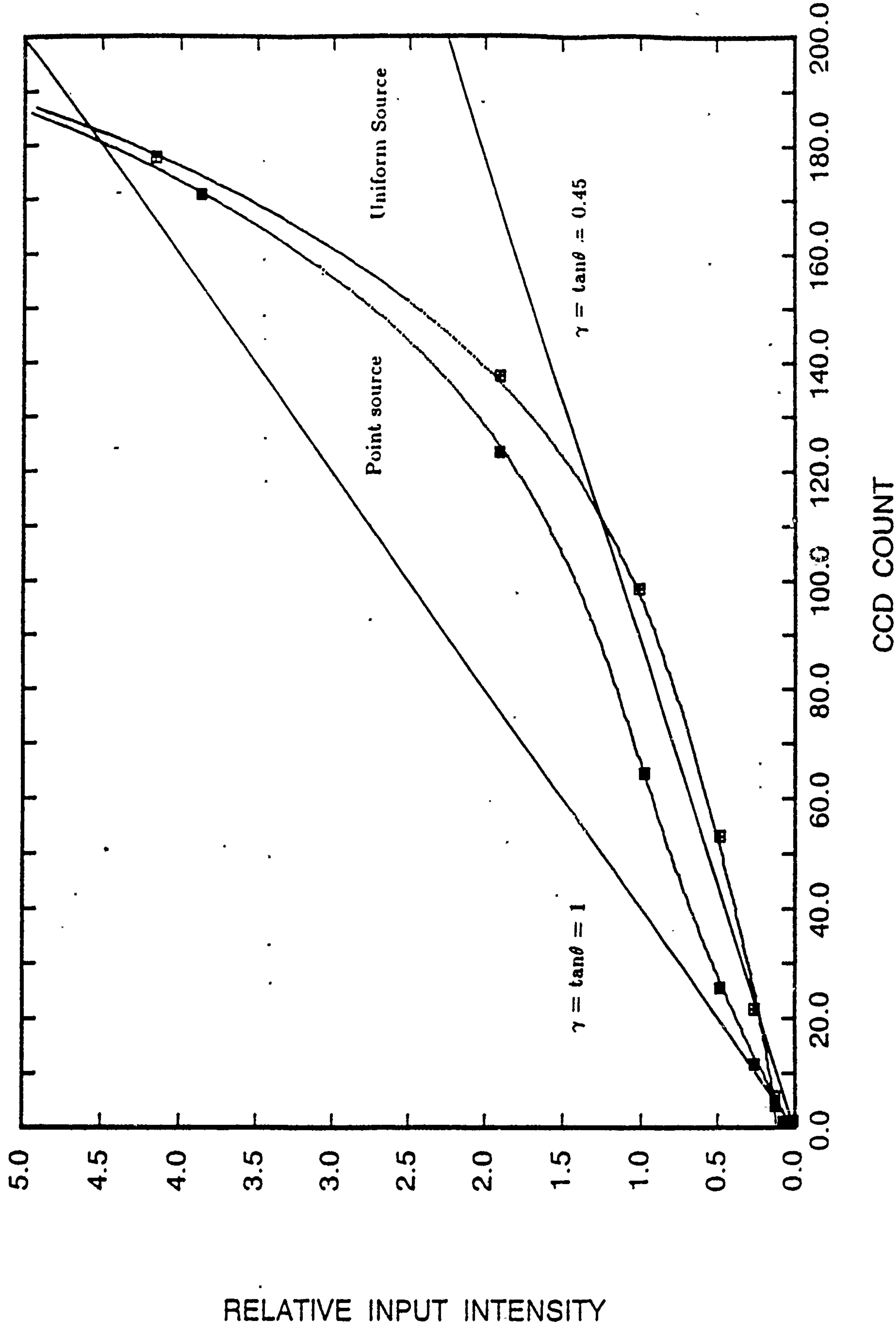

Mean Cloud Cover
1984 – 1986
Sunspot
Anderson Mesa
Blue Mesa
Kitt Peak
Flat Top
Percentage Cloud Cover
0
10
20
30
40
50
60
70
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


SLOTTED
STOP
MICROMETER
FILTER
CCD

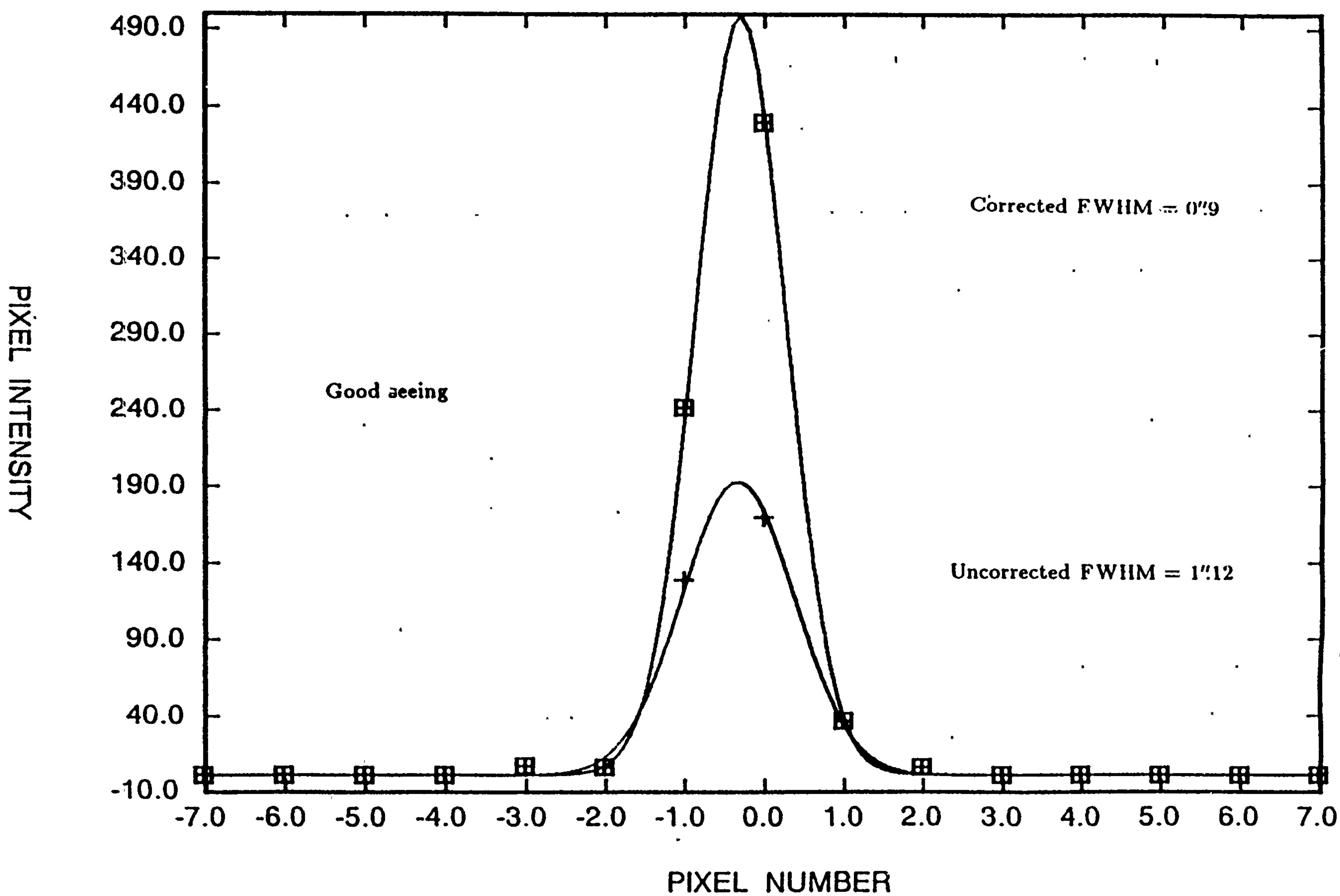


FOCUS DEVICE
+
PULNiX CCD CAMERA
L
a
X
b
L=6mm
X = L / (b/a + 1)
HIGH
RESOLUTION
MONITOR
IBM-AT
COMPATIBLE
CLONE
IMAGE
TECHNOLOGY
GRABBING
BOARD
MONITOR
ON-LINE
CPU
1.2 M
FLOPPY
DRIVE
HARD
DISK

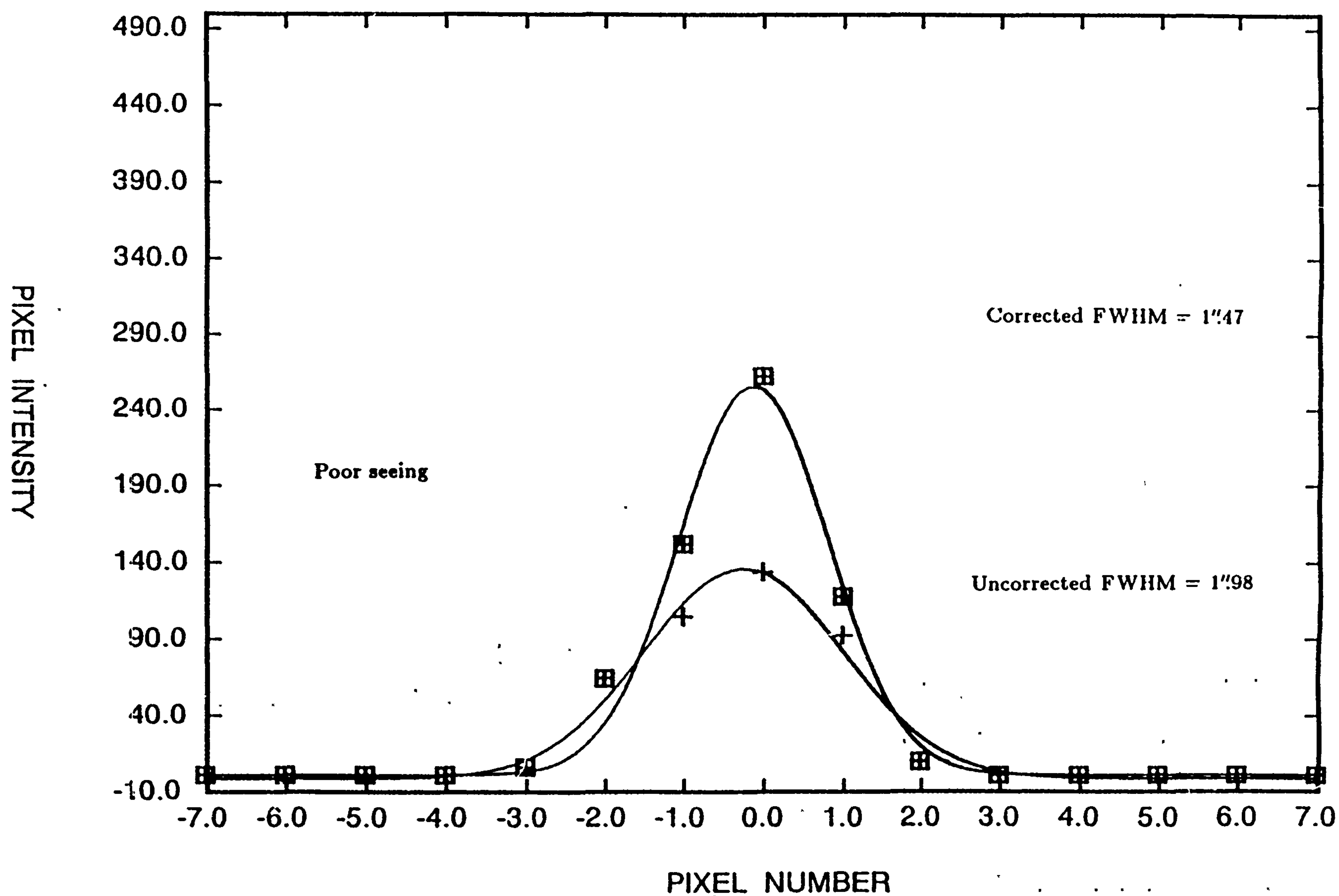


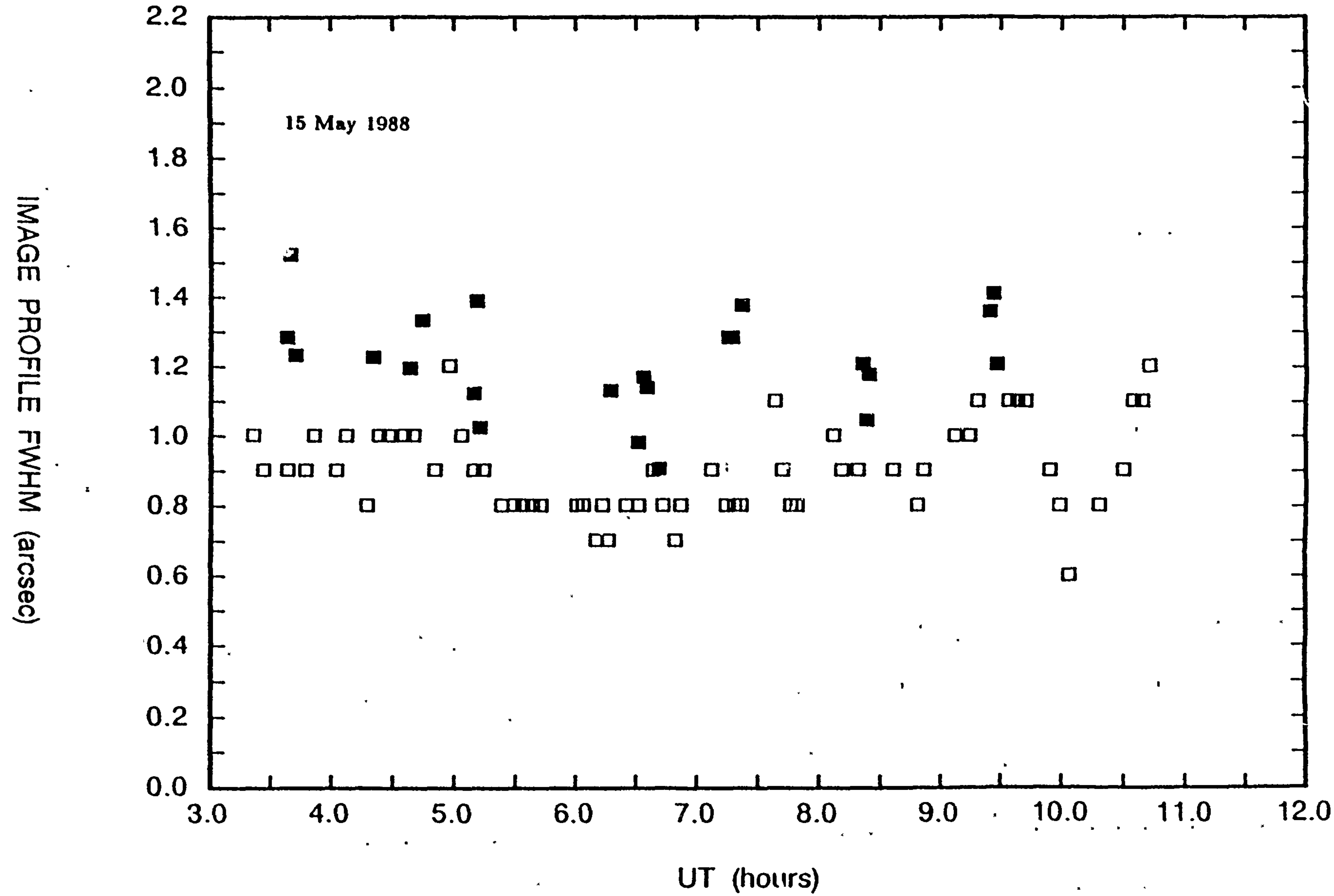


Uniform Source
Point source
γ = tanθ = 0.45
γ = tanθ = 1
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
200.0
CCD COUNT
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
RELATIVE INPUT INTENSITY

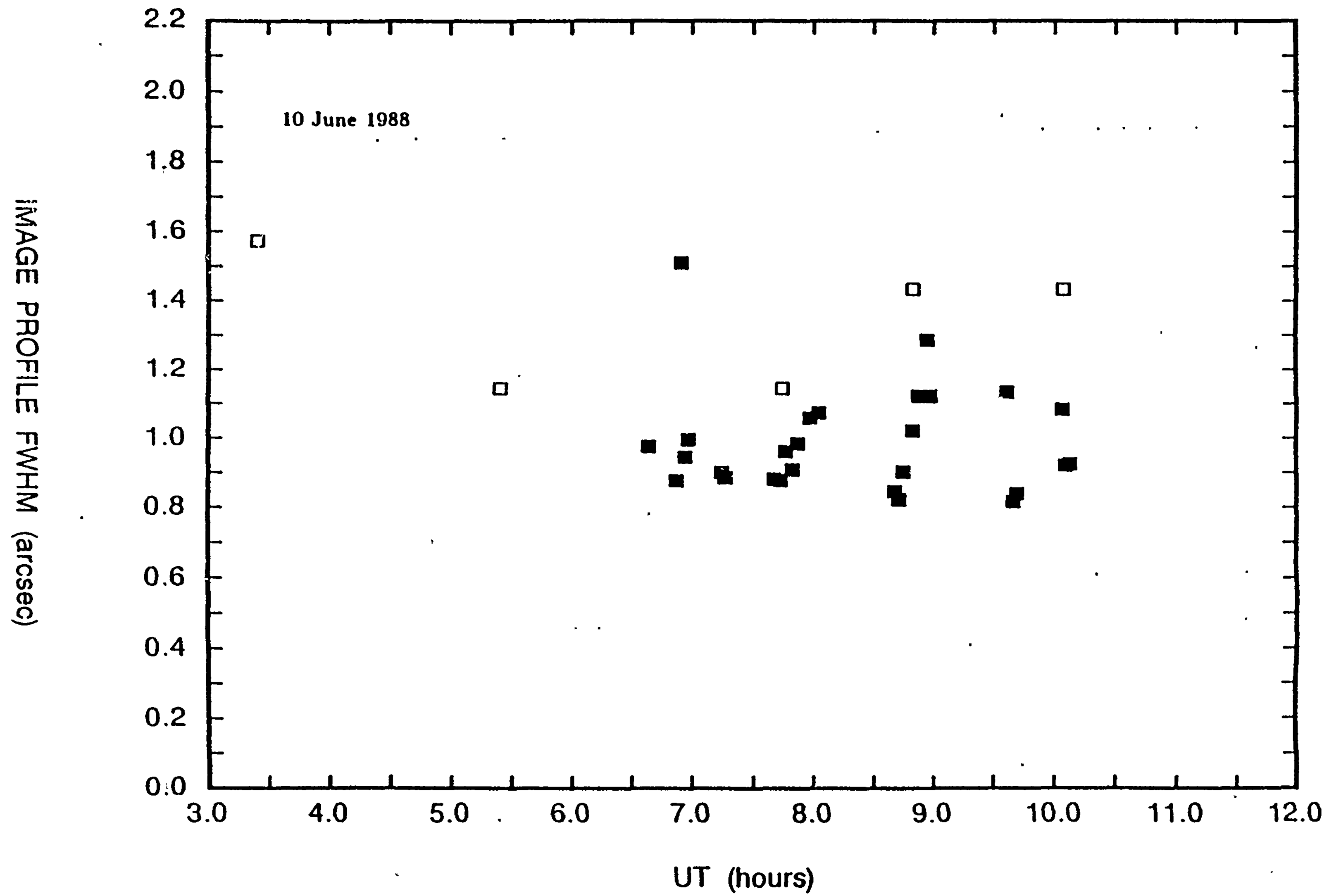


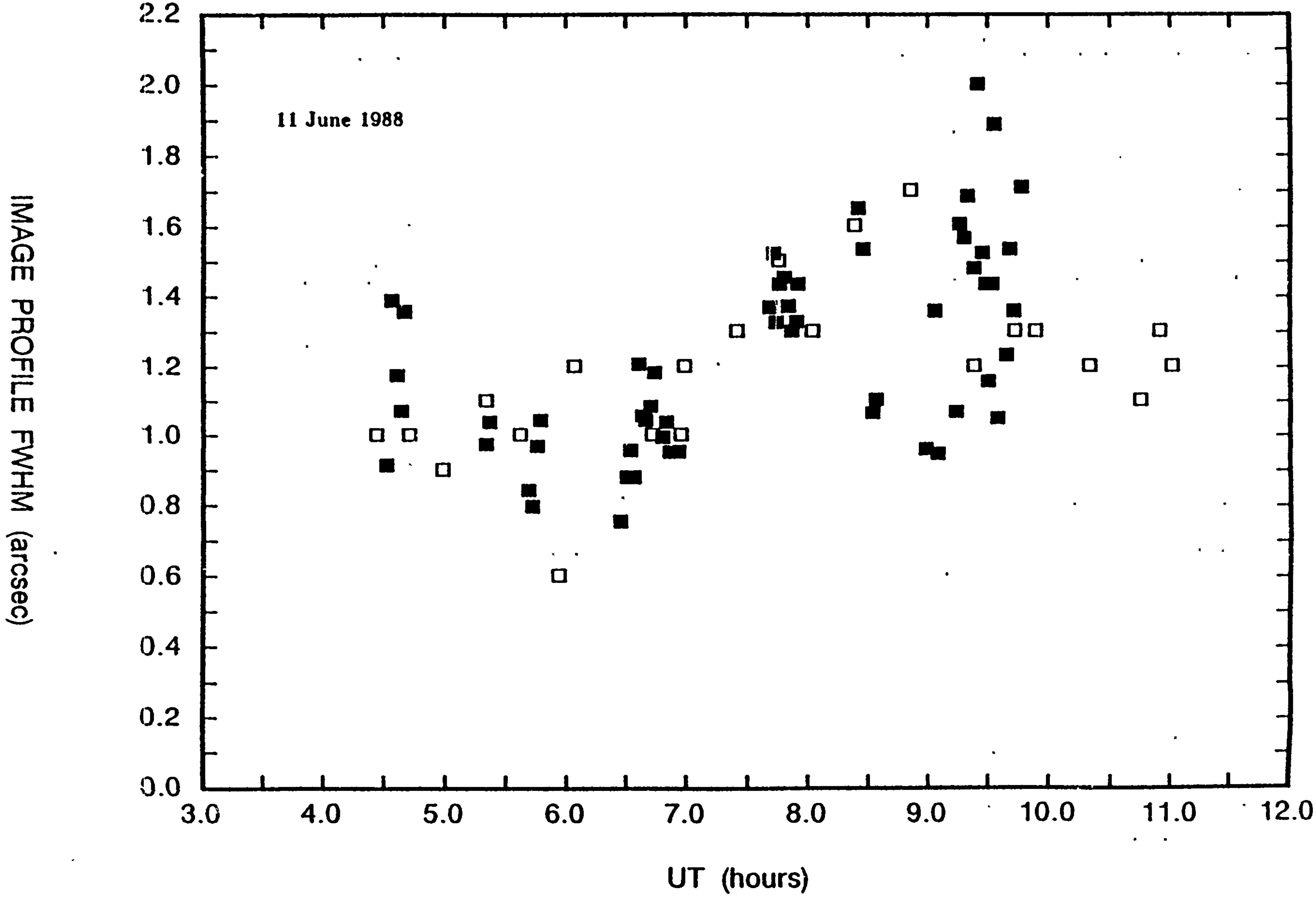
Corrected FWHM = 0.″9
Uncorrected FWHM = 1.″12
Good seeing
PIXEL INTENSITY
490.0
440.0
390.0
340.0
290.0
240.0
190.0
140.0
90.0
40.0
-10.0
-7.0
-6.0
-5.0
-4.0
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
PIXEL NUMBER

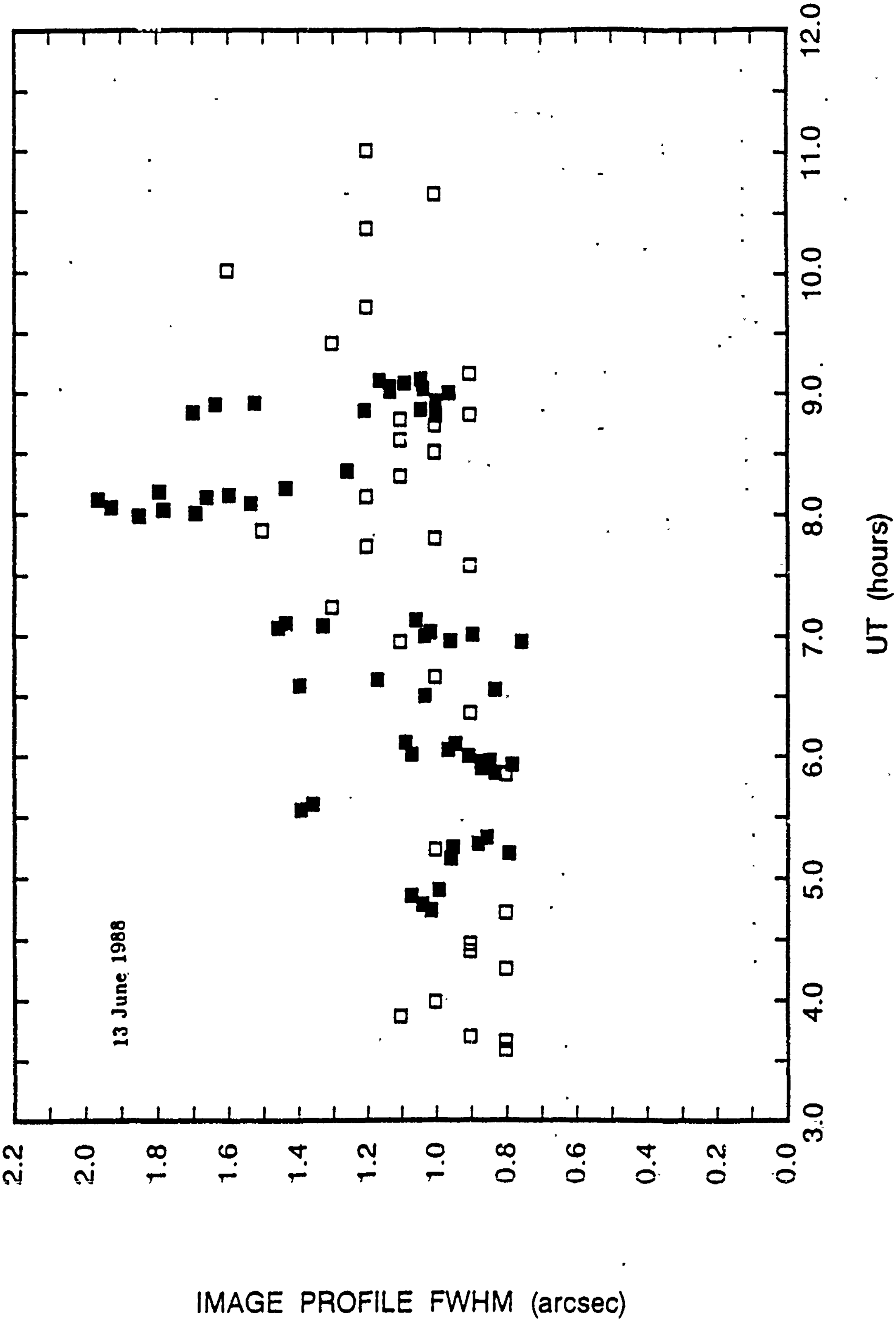

Corrected FWHM = 1''.47
Uncorrected FWHM = 1''.98
Poor seeing
PIXEL INTENSITY
PIXEL NUMBER

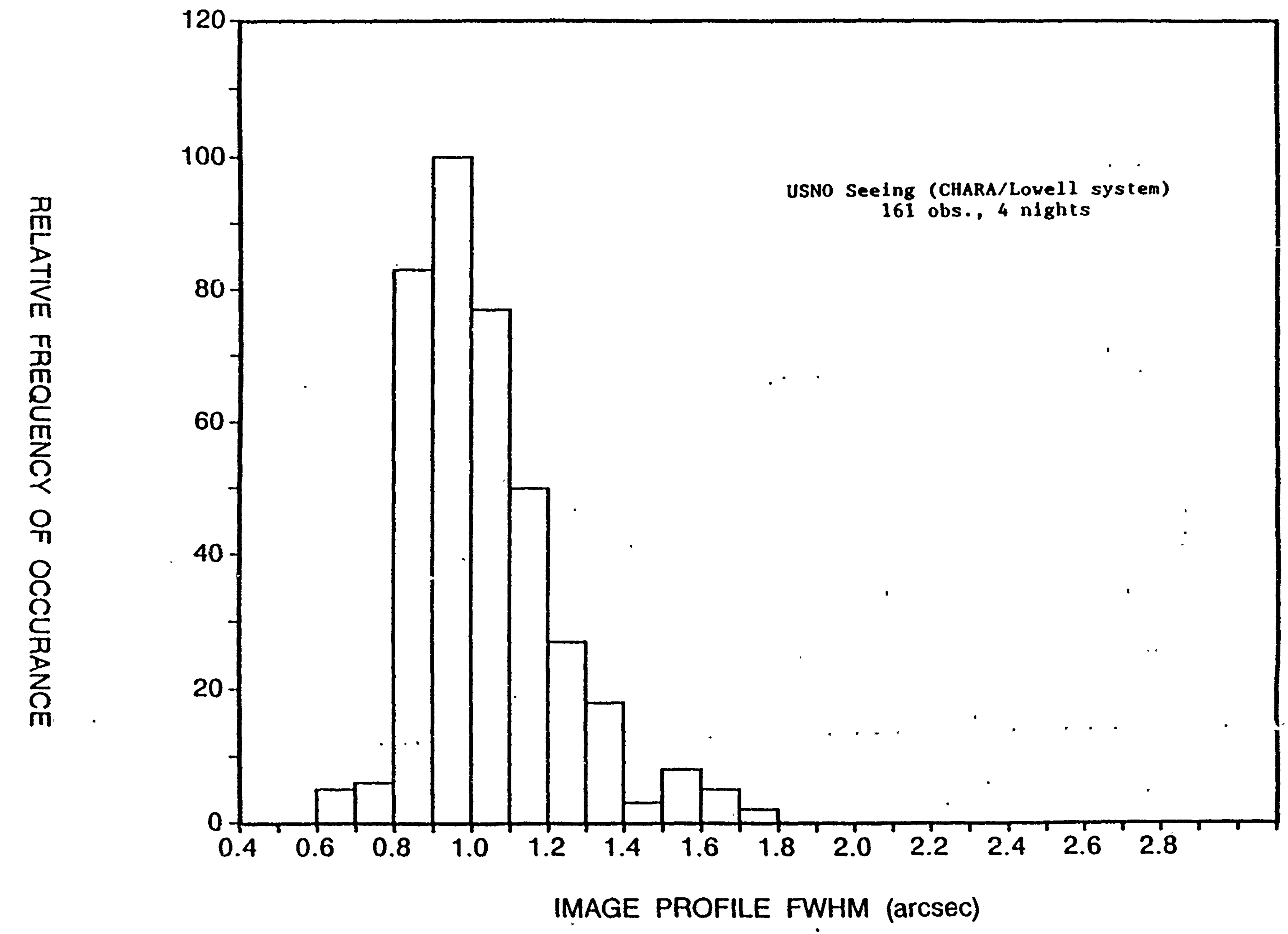


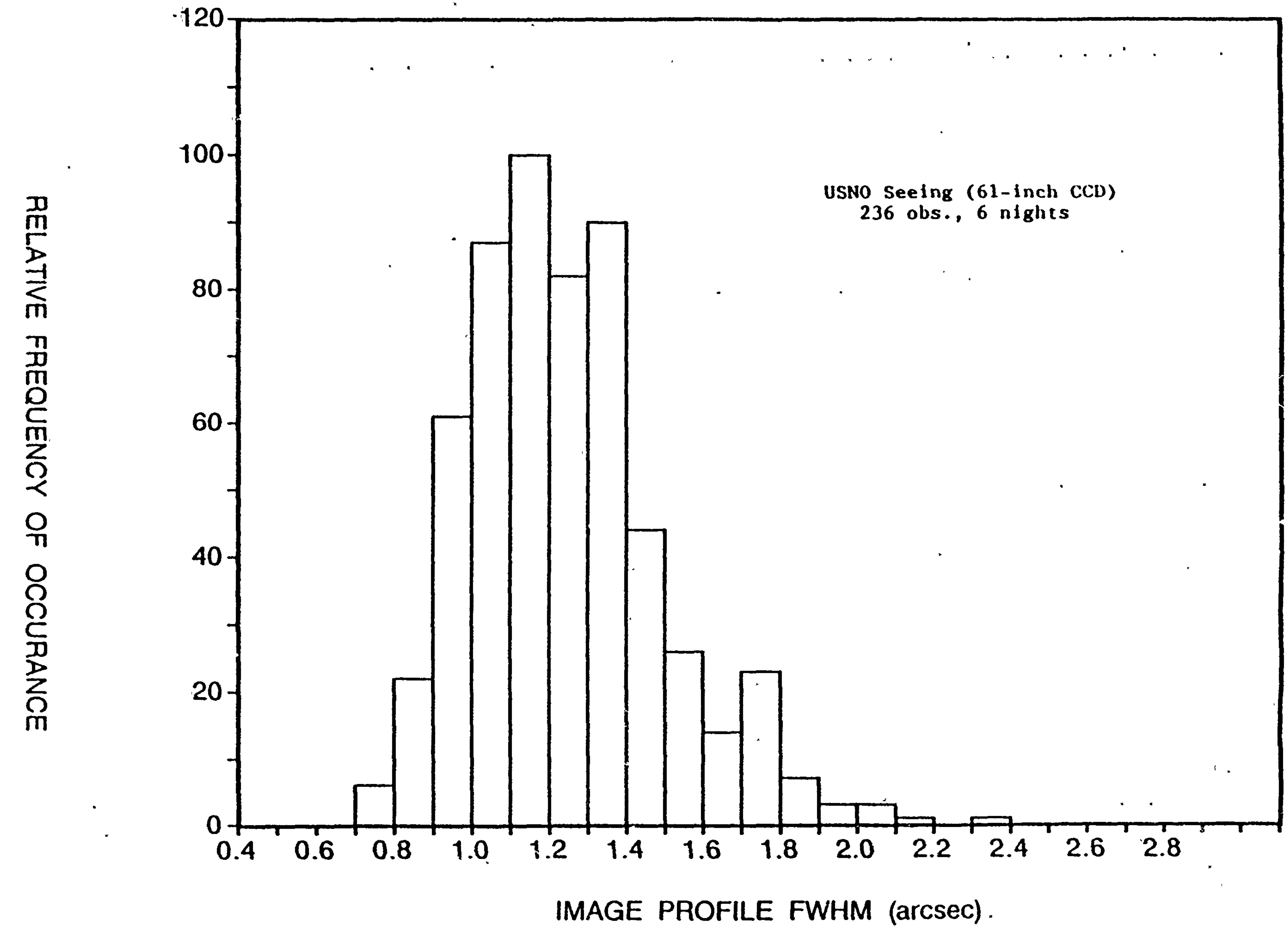
15 May 1988
IMAGE PROFILE FWHM (arcsec)
UT (hours)
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0

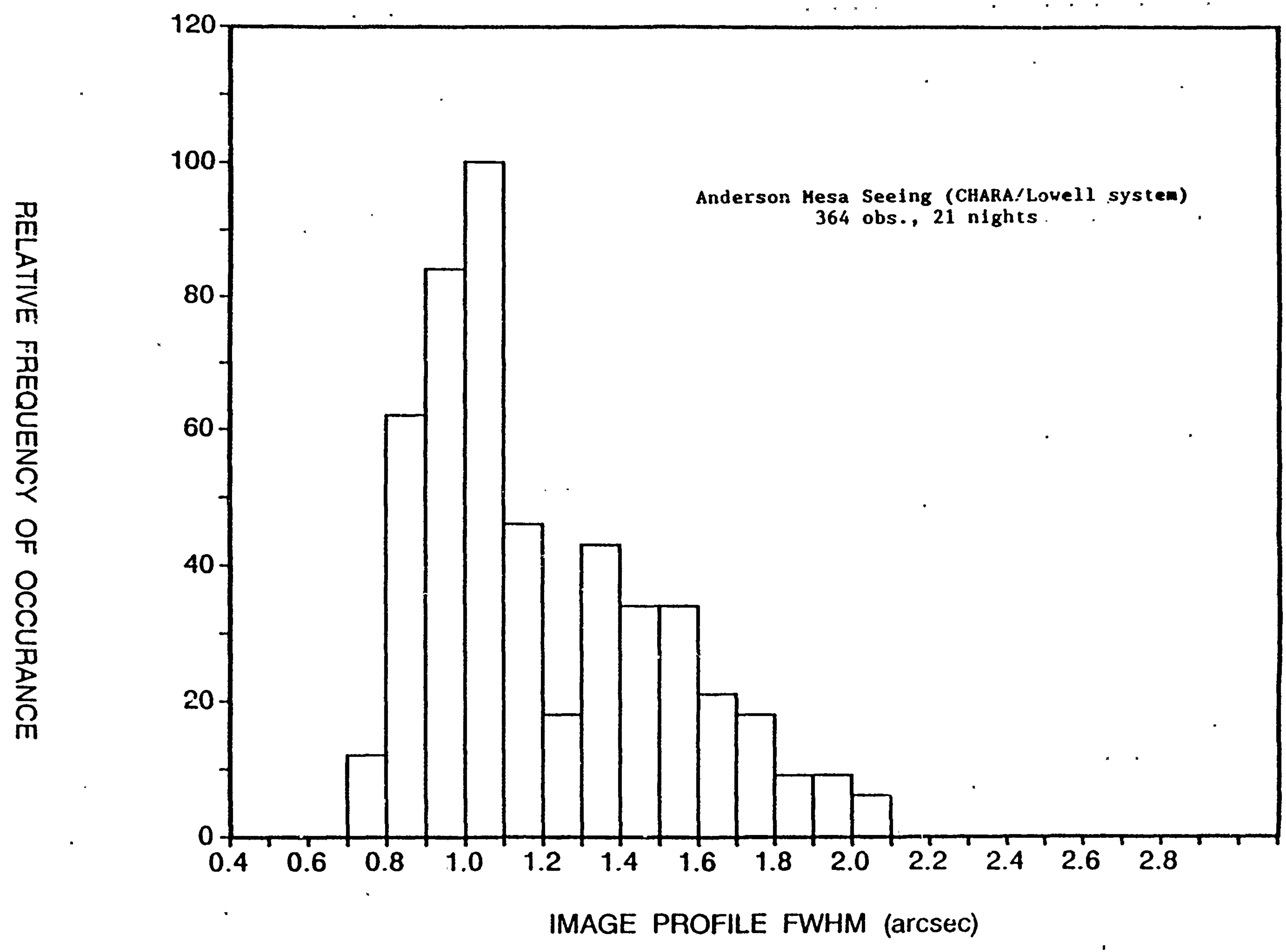

10 June 1988
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
IMAGE PROFILE FWHM (arcsec)
UT (hours)


11 June 1988
IMAGE PROFILE FWHM (arcsec)
UT (hours)
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0

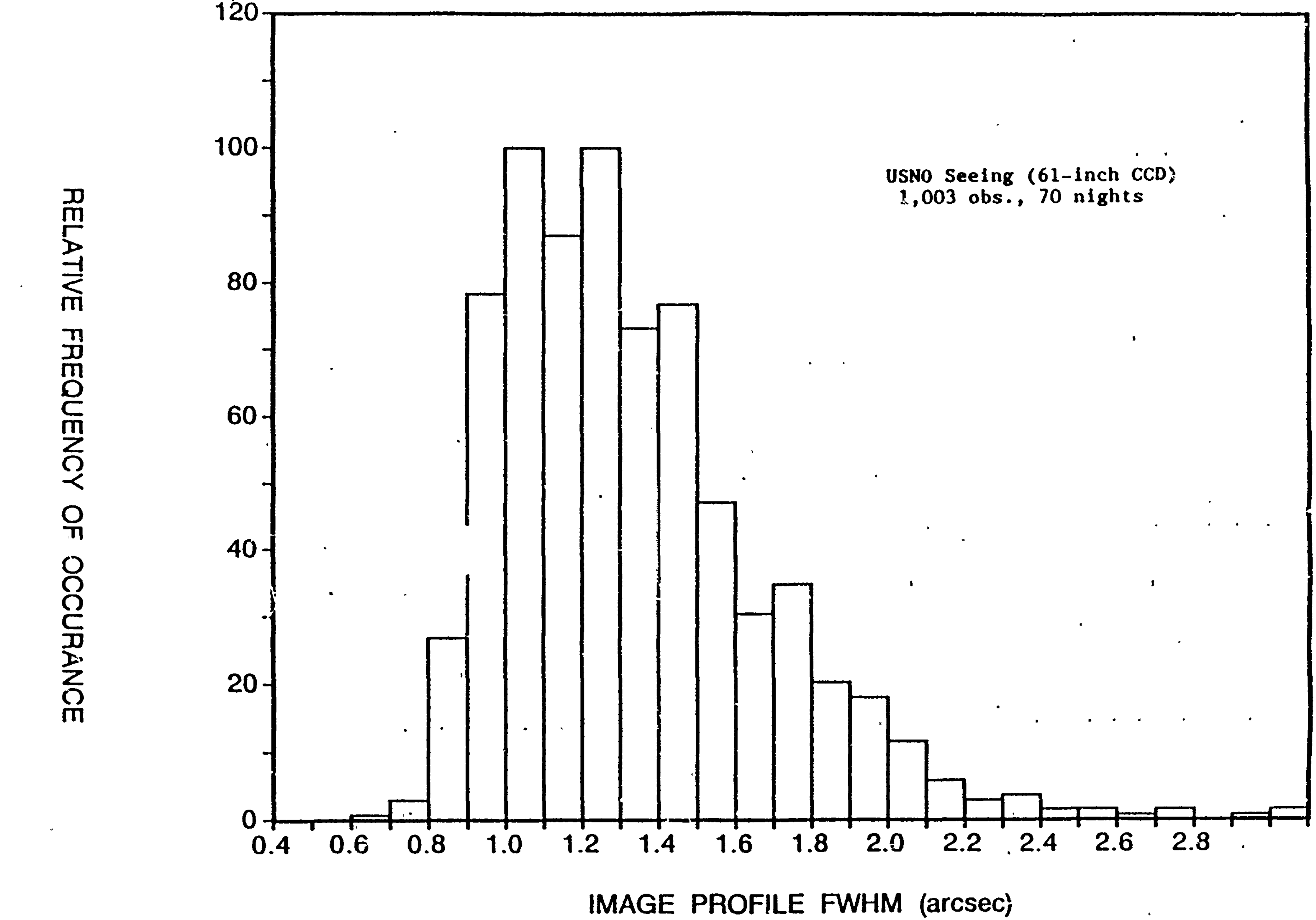

13 June 1988
UT (hours)
IMAGE PROFILE FWHM (arcsec)


USNO Seeing (CHARA/Lowell system)
161 obs., 4 nights
RELATIVE FREQUENCY OF OCCURANCE
120
100
80
60
40
20
0
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
IMAGE PROFILE FWHM (arcsec)

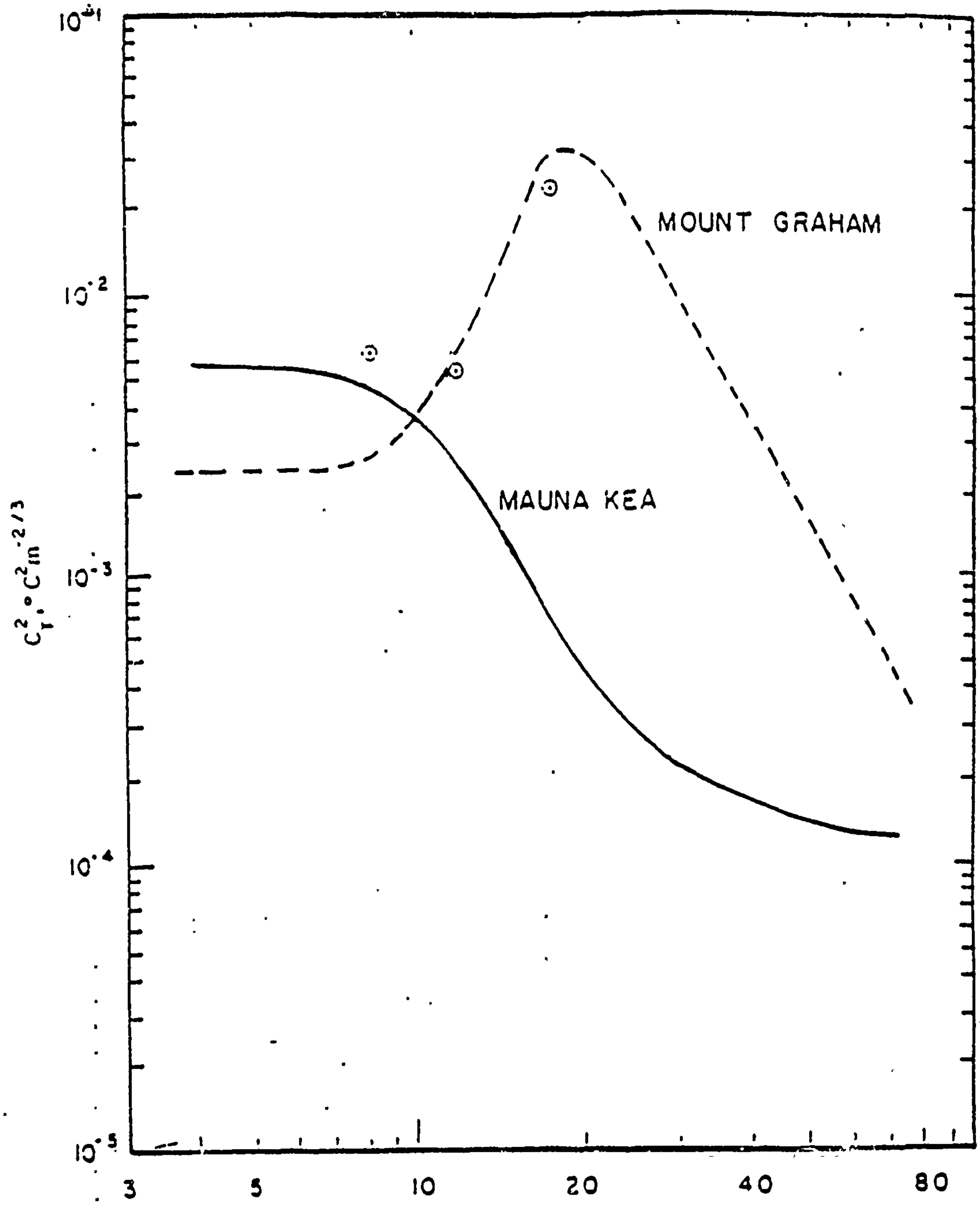

USNO Seeing (61-inch CCD)
236 obs., 6 nights
RELATIVE FREQUENCY OF OCCURANCE
IMAGE PROFILE FWHM (arcsec)
120
100
80
60
40
20
0
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8



Anderson Mesa Seeing (CHARA/Lowell system)
364 obs., 21 nights
120
100
80
60
40
20
0
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
RELATIVE FREQUENCY OF OCCURANCE
IMAGE PROFILE FWHM (arcsec)



USNO Seeing (61-inch CCD)
1,003 obs., 70 nights
RELATIVE FREQUENCY OF OCCURANCE
0
20
40
60
80
100
120
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
IMAGE PROFILE FWHM (arcsec)



HEIGHT, METERS.

Results in speckle photometry

W. G. Bagnuolo, Jr., D. J. Barry, B. Mason, E. G. Dombrowski

Center for High Angular Resolution Astronomy
Georgia State University, Atlanta, Georgia 30303

ABSTRACT

Algorithms for reconstruction of isoplanically blurred point source pairs are considerably simpler and faster than full-blown image reconstruction techniques. Traditional autocorrelation approaches suffer from a 180 degree ambiguity, however, and only yield order of magnitude estimates for brightness ratios. A new asymmetric algorithm is here presented: the "Directed Vector Autocorrelation" (DVA), which is a rapid alternative to vector autocorrelation. Together with the "Fork Algorithm," a directional filter for estimating brightness ratios, the DVA algorithm has been used to resolve ambiguous orbits and produce differential color photometry for several binary stars.

1. THE DVA ALGORITHM

Binary star speckle interferometry is traditionally analyzed with autocorrelation-based algorithms, which suffer from an inherent 180 degree position-angle ambiguity. Our own extensive program of binary measurement has principally been conducted with a vector-autocorrelation (VA) algorithm of this type implemented in hardware. This device gives a 1 bit (on/off) digitization of two-dimensional speckle frames. The hard-wired VAC then calculates a 2-d histogram of all separations among the sample of "on" pixels, an operation that can be quickly carried out in hardware, and provides autocorrelograms from which the relative positions of the components can be accurately extracted, albeit with the quadrant ambiguity inherent in this process.

All astrophysically significant quantities are independent of absolute orientation of orbit, so long as consistency is maintained. Nevertheless, absolute quadrant determination is useful in referencing long-separated measurements, or for comparing visual apastron to speckle periastron measures. For orbits with known periods or with close time-coverage, each measurement can be incrementally referenced to the previous, or to a known orbit, which reveals the true quadrant at epoch. But in a poorly measured orbit, a highly eccentric pair can masquerade as a slow-moving nearly circular system of twice the period, since the rapid quadrant changes at periastron often cannot be followed, by observing time constraints, even if the periastron separation permits measurement. This is the case for a small but significant number of stars on our program (roughly 50 out of some 2000), which have been reanalyzed to establish absolute orbital quadrant and to ensure consistency of quadrants at different epochs. For example, we have shown (McAlister *et al.* 1988) that the motion of the Hyades binary Finsen 342 is consistent only with a 6 yr eccentric orbit rather than with the 13 yr circular orbit assumed in most previous analyses.

In order to eliminate the 180 degree ambiguity the full complexity of imaging algorithms is neither necessary nor desired. However, algorithms must use relative pixel brightnesses rather than pure thresholding. Each speckle frame therefore should be digitized to a resolution of at least eight bits. Modest cost video hardware is now available that can return 512x512 pixel frames at nearly video rates with eight bits per pixel. Analysis can then be performed either with the primary CPU or with a dedicated coprocessor.

For quadrant determination, we have developed the Directed-Vector-Autocorrelation Algorithm (DVA), a simple modification of the VA. In this algorithm the digital intensities as well as the (x, y) locations of all the pixels in a frame above a threshold (or the brightest n pixels) are saved, so that we now require 3 bytes instead of 2 per pixel. Suppose two pixels have intensities I_1 and I_2 and locations (x_1, y_1) and (x_2, y_2), respectively. The 2-d histogram of the separation is incremented in location $(x_2 - x_1, y_2 - y_1)$ if $I_1 \geq I_2$ and in location $(x_1 - x_2, y_1 - y_2)$ if $I_1 \leq I_2$. That is, a direction is given to the separation, in the sense of from brighter to dimmer pixel, hence the name of the algorithm. Because the DVA is only a bit more complex than the VA, the software is easily implemented in C and Assembler.

Table 1. Partial List of Quadrant Determinations.

Star	*WDS Desig*	*Epoch*	Θ	ρ	*Quad*	*S/N*
McA 1	00323+0657	1984.9991	87.23	0."1314	$\mathcal{S}$†	2.5
McA 7	02366+1226	1985.8376	311.67	0."0644	$\mathcal{S}$†	2.0
McA 7	02366+1226	1987.7625	131.10	0."0651	$\mathcal{N}$†	2.0
McA 7	02366+1226	1988.8888	169.57	0."0505	$\mathcal{N}$†	2.6
McA 24	06034+1942	1988.6637	72.76	0."0544	$\mathcal{N}$	2.3
McA 40	14403+2158	1987.2643	82.15	0."0655	$\mathcal{N}$	3.1
McA 46	17103−1926	1989.3040	116.01	0."1370	$\mathcal{N}$†	2.3
McA 63	20474+3629	1984.7013	102.9	0."052	$\mathcal{N}$†	16.9
CHARA 7	02475+4416	1984.0576	104.45	0."1612	$\mathcal{N}$†	2.9
CHARA 10	03271+1845	1985.8403	110.01	0."0767	$\mathcal{S}$	2.2
CHARA 15	04120+5016	1983.0637	154.77	1."2609	$\mathcal{S}$	2.9
CHARA 19	04493+3235	1984.0576	148.61	0."0423	$\mathcal{N}$†	25.6
CHARA 25	06580+0218	1989.3112	39.4	0."918	$\mathcal{S}$†	2.2
CHARA 45	15183+2649	1984.3837	65.46	0."3390	$\mathcal{S}$†	18.5
CHARA 55	16254+3724	1986.4099	175.74	0."1677	$\mathcal{N}$†	2.7
CHARA 69	18218−1619	1985.4899	10.68	0."0913	$\mathcal{S}$†	2.1
CHARA 92	20050+2313	1983.8425	47.67	0."0506	$\mathcal{S}$†	2.8
CHARA 92	20050+2313	1985.5177	54.95	0."0516	$\mathcal{N}$	3.6
CHARA 98	20285−2410	1983.4258	81.41	0."2367	$\mathcal{S}$†	19.6
CHARA 142	01070+3014	1988.6661	110.99	0."0891	$\mathcal{S}$	3.7
CHARA 143	08125−4616	1989.3057	159.04	0."0453	$\mathcal{N}$†	2.2
ADS 755	00550+2338	1989.7118	285.56	0."3930	$\mathcal{N}$§	8.6
ADS 1630	02035+4223	1989.7119	107.33	0."5715	$\mathcal{S}$§	7.5
ADS 2200	02537+3820	1989.7122	258.11	0."1808	$\mathcal{S}$§	5.2
ADS 3064	04136+0743	1989.7123	316.99	0."0572	$\mathcal{N}$§	2.7
ADS 3135	04187+1632	1989.7123	62.27	0."2652	$\mathcal{N}$§	2.7
ADS 3172	04236+4226	1989.7123.	155.82	0."3468	$\mathcal{S}$§	4.8
ADS 3210	04256+1852	1989.7123	26.15	0."2349	$\mathcal{N}$§	7.4
ADS 6993	08468+0625	1984.0553	195.4	0."266	$\mathcal{S}$	4.1
ADS 6993	08468+0625	1984.0608	195.1	0."271	$\mathcal{S}$	3.4
ADS 8863	13202+1747	1986.4067	327.7	0."058	$\mathcal{N}$	2.1
HR 657	02157+2503	1989.7122	45.14	0."1907	$\mathcal{N}$§	2.7
HR 719	02280+0158	1989.7122	34.75	0."5146	$\mathcal{N}$§	5.4

†*Published quadrant is* 180° *in error.*

§*No published quadrant.*

The resulting DVA "autocorrelogram" for a binary star appears similar to that produced by "Shift-and-Add" (Bates and Cady, 1980) with "center," "principal," and "ghost" spots. The true position angle is given by the position of the principal spot relative to the center spot. Analysis software has been developed for extraction of these spots from a radial noise profile by boxcar subtraction, paraboloid boxcar subtraction, and smoothed radial subtraction. In rectangular boxcar subtraction, an image is convolved with a small $(n \times n, 5 < n < 21, n$ odd) kernel with a center value of unity and an outlying rectangular area of uniform negative value summing to minus unity. The effect is to measure the variation of the image from a smoothed version, thus subtracting the relatively even and symmetric noise profile. Such a kernel is decomposable into x and y one-dimensional components for rapid calculation. Parabolic boxcar subtraction uses a similar principle, with a weight of $1 - r^2/r^2_{max}$, again yielding a decomposable kernel. Smoothed radial subtraction breaks the entire image up into radial zones over which an average noise value is ascertained, and the resulting $N(r)$ curve is used to subtract the background to reveal peaks. Peaks are measured from an image filtered by the previous techniques by least squares fit of a biquadratic to a $(n \times n, n = 3, 5, 7)$ window around a maximum value selected by a cursor. This is an elaboration of software used to reduce most of the 8,000 autocorrelograms previously measured and published by CHARA. Table 1 lists some quadrant determination

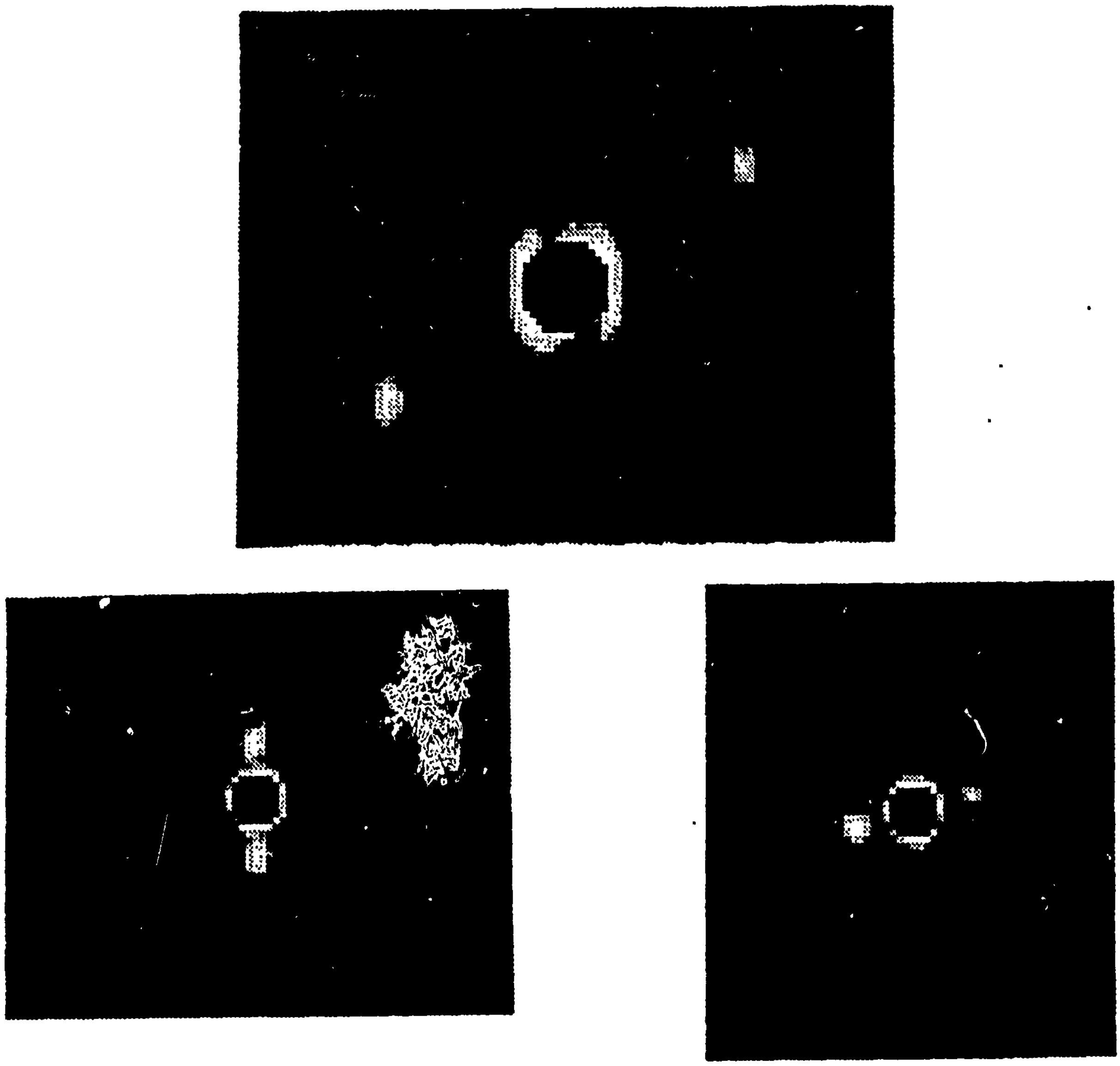


Figure 1–a,b,c. Top, Left, Right: γ Persei, Finsen 342, ADS 2200.

results, based on runs of 250 frames each. We plan to publish a more complete table of quadrants shortly.

2. THE FORK ALGORITHM

The Fork Algorithm (Bagnuolo, 1988) selects from speckle frames pixel quadruples (I_1, I_2, I_3, I_4) passing a brightness threshold test $I_2 + I_3 > K > k(I_1 + I_4)$ and with separation and position angle like "tines of a fork," matching that of the target system. Each such quadruple can be viewed as a miniature recurrence of the resolved pair (I_2, I_3), with background level (I_1, I_4) and is used to form an estimate of the brightness ratio. (The crude ratio I_2/I_3 may be corrected by I_1 and I_4 as described in the above reference.) A histogram of these ratios, summed over many frames, yields an estimate of the brightness ratio, with greatly improved signal to noise for a given number of frames over standard techniques (Shift and Add, Triple Correlation, *etc.*), as verified by competitive analysis of simulated frames. (Bagnuolo, 1988). (Other algorithms can of course be applied to more general objects.) Although designed for differential photometry, the Fork Algorithm also provides quadrant information and can be used to verify the DVA results for a system.

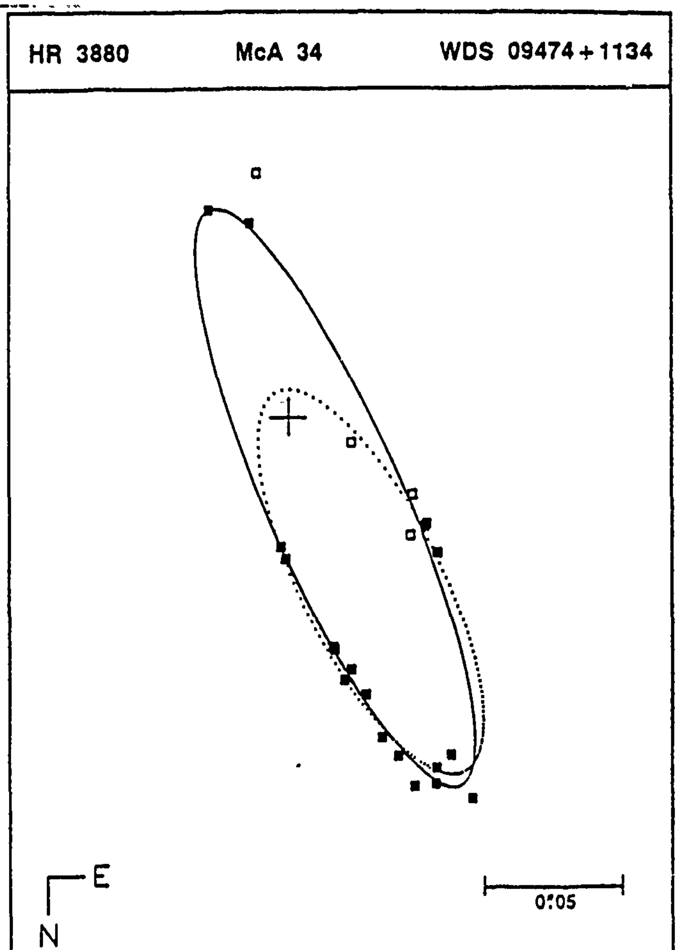


Figure 2. Orbit of McA 34. Dotted line- Tokovinin (1987), Solid line-CHARA (1989). Filled squares- CHARA observations, Light squares, other observations.

3. HARDWARE

The two major bottlenecks in real-time processing are the I/O bus speed, necessary to transfer data from video digitizing hardware to the CPU or coprocessor, and the frame-analysis time. A full video data feed may represent 30 Mbyte/s. In our implementation, an Imaging Technologies PC-Vision digitizing board records video frames at 256×256 resolution, and of these, 128×128 windows are extracted for analysis. This represents only a 0.5 Mbyte/s load on the bus of the Intel 386-based PC. Processing of several hundred of the brightest pixels is performed by the DVA algorithm, which can usually be done within four frame times, dependent on the pre-threshold level selected. This is approximately a quarter the speed of the hardware autocorrelator. We have found it usually more convenient to post-process data which has been recorded on a Sony 8mm "Video 8" unit, removing the constraint of real-time analysis. In this technique, up to 250 frames are digitized and stored in extended memory at *ca.* 10 frame/s, and then analyzed after acquisition by both DVA and FORK. It is also possible to digitize selected frames, such as those with momentarily superior seeing and better defined speckles, due to the stability of the Sony's freeze frame capability.

The vector-difference procedure will soon be performed by a slave Motorola DSP56001 processor mounted on the PC bus. This algorithm, which is quadratic with pixel count, will operate on the pixel list provided by the primary CPU. This should permit real-time processing of frames with up to 800 thresholded pixels. The Fork algorithm, too, is amenable to implementation in real time, although it requires prior knowledge of position angle and separation. A planned system will utilize two coprocessors, in which the central proce. sor will generate thresholded

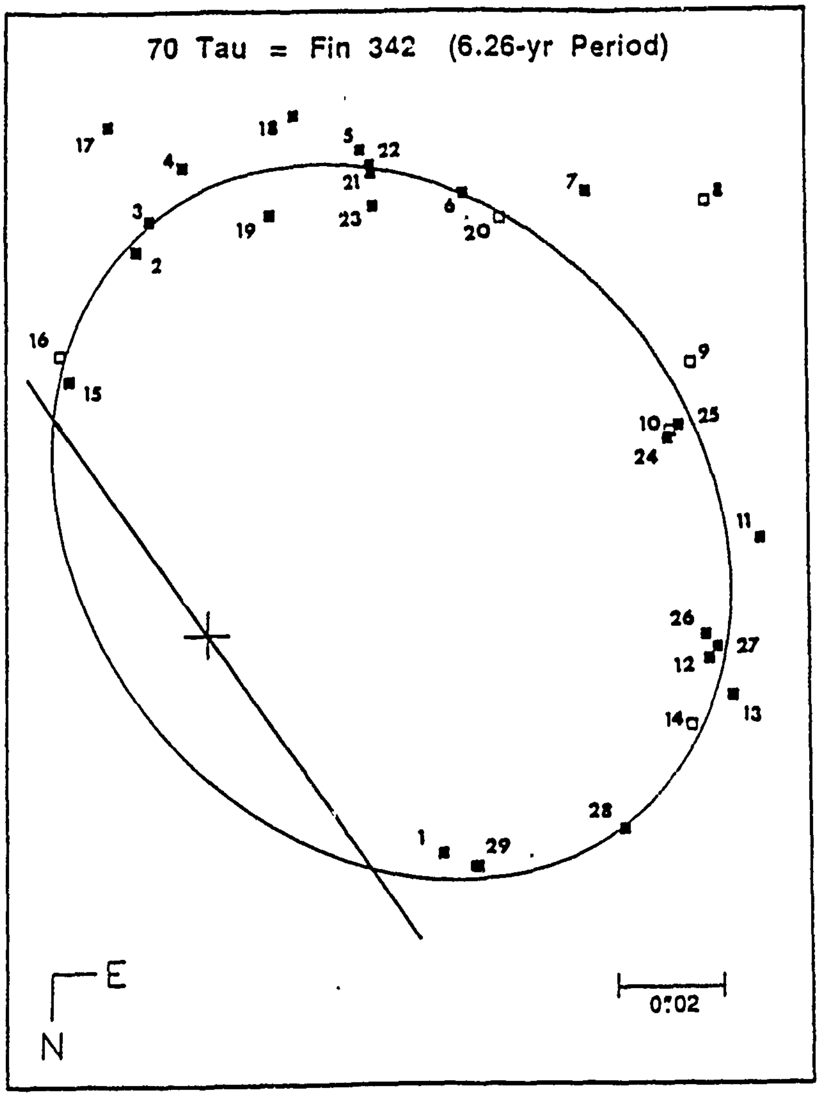


Figure 3. Finsen 342 orbit of 6.264 yr. Data symbols as in Figure 2.

pixel lists, one of which will drive a DVA coprocessor. After a peak is detected and measured, the coordinates will be fed to the FORK coprocessor, which will begin operating on the same thresholded pixel list used by the DVA processor. This coprocessor will need to read auxiliary pixels from frame memory to complete the fork quadruples, but the primary limitation will be from bus throughput considerations rather than processing speed.

Most of the data has been gathered with the CHARA intensified CCD camera (McAlister *et al* 1984). Flat-fielding is necessary because of a gradual loss of sensitivity due to exposure of the micro-channel plate near the center of the Field of view. A potentially more serious problem is detector non-linearity. In order to measure non-linearity effects, as well as check the performance of intensity-ratio algorithms in general, we have generated calibration speckle frames by inserting a calcite crystal of either 25 or 4 mm thickness into the optical path of the speckle camera. The birefringence of the calcite crystal produces two speckle patterns with a fixed offset and with orthogonal polarizations. The intensity ratio of the artificial binary can be varied by rotating a polarizing filter relative to the calcite crystal. If there is the position angle for which the two "binary" components have equal intensity, then the intensity ratio varies as $tan^2(\theta - \theta_0)$. The thicker calcite crystal generates a clearly separated paired image typical of a 1.5 arcsecond binary under normal seeing, whereas the thinner crystal produced a "binary" of 0.2 arcsecond effective separation.

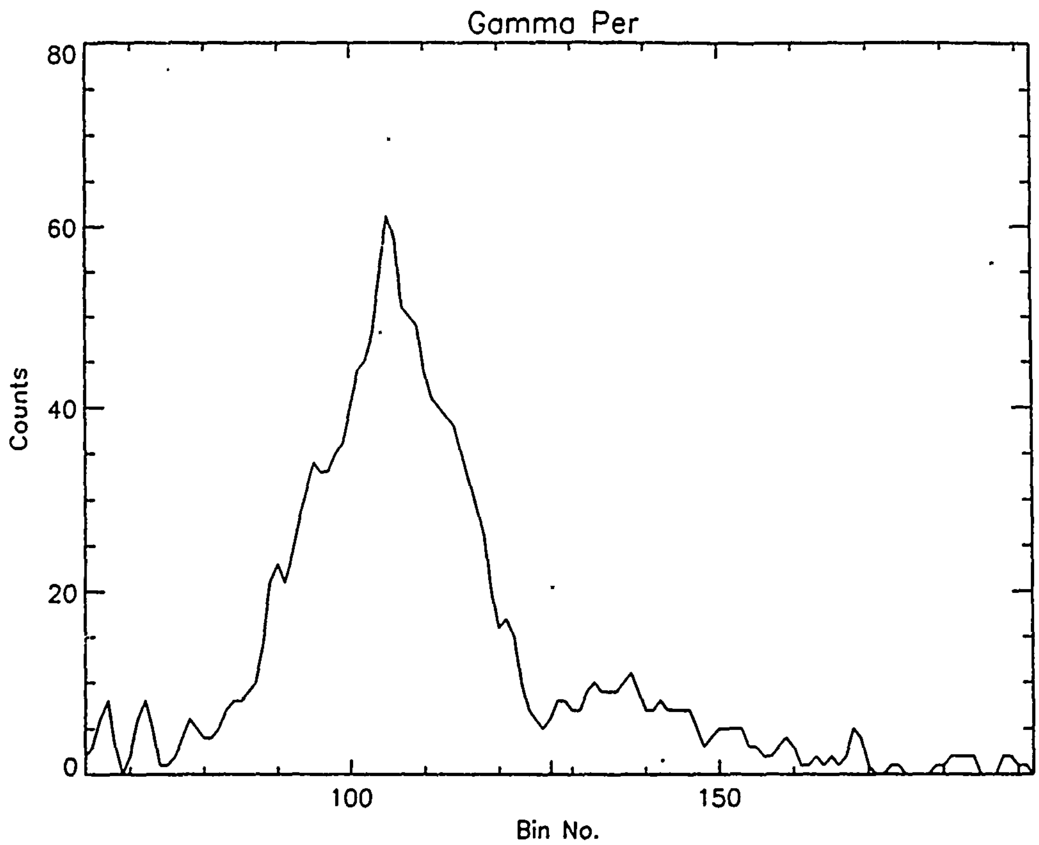


Figure 4. Fork Algorithm intensity fraction histogram for γ Persei.

These simulated binary stars with known intensity ratios permit calibration of a curve to compensate for camera non-linearity effects.

Through a cooperative agreement with SAO, we anticipate receiving a PAPA camera by February. This device, which is inherently linear and capable of a much fainter magnitude limit than our existing camera, will be tested and integrated into observing programs during the next several months.

4. QUADRANT RESULTS

Figures 1a, 1b, and 1c are DVA "autocorrelograms" for γ Persei, Finsen 342, and ADS 2200 respectively and illustrate how the position ambiguity can be removed. In each case the brightest 300 pixels of 200 frames of data were used. The true position angles are in the direction of center to primary spots. Center spot removal and parabolic boxcarring subroutines were used for each analysis.

Figure 2 shows the orbit for the star McA 34 (HR 3880, WDS 09474+1134). The published orbit by Tokovinin (1987), shown by the dotted line, has a period of 9.70 years and semi-major axis a = 0.″075. However, by resolving the quadrant ambiguity at two key points in the orbit with DVA, we obtain an orbit shown in solid line with a period

of 15.167 years and a semi-major axis of a = 0."1120. Note that changes in period and semi-major axis can greatly affect the computed masses of the stars.

Another example of a quadrant determination, taken from McAlister *et al.*, 1988, shown in Figure 3, is of the Hyades binary Finsen 342. We showed that the orbit was an eccentric one of 6.264 years, as proposed originally by Peterson and Solensky (1987), and not the 13 year circular orbit assumed in most previous analyses.

Finally, Table 1 presents a list of the quadrant data determined to date.

5. FORK RESULTS

Gamma Persei is a well-know example of a star with a composite spectrum and a binary resolvable with speckle-interferometry. According to previous estimates by Popper and McAlister (1987), it consists of A3 and G8 III stars, for which the masses are 2.0 and 3.0 Solar Masses. As a bright, "poor-man's Capella," γ Persei provides a case-study of the application of the Fork Algorithm in estimating intensity ratios. Several sets of data consisting of 200 frames each were digitized from the Sept. 1989 KPNO 4-m run. These data were flat-fielded, slightly smoothed, and a non-linearity correction was applied (based on the Calcite results mentioned above). Applying the Fork algorithm produced the histogram shown in Figure 4. The histogram is of the fraction of total intensity in the secondary, where bin 63.5 is 0.0, and bin 127.5 is 0.5. The peak at bin 105 corresponds to Δm of 0.80. Because several repeated runs gave results to within 0.02 mag., it is likely that most of the uncertainty in this result comes from systematic rather than random errors. Such errors could be from residual uncorrected nonlinearity, a deviation of the actual photometric passband from Strömgren y, etc. A similar preliminary result is $\Delta m = 0.50 \pm 0.05$ in Strömgren b. The astronomical implications of recent Capella data in terms of the H-R diagram have been discussed by Bagnuolo and Hartkopf (1989). Similarly, for γ Persei, the spectral types implied by the Δm's in y and b above are significantly different from those assumed in Popper and McAlister (1987). (The V magnitude difference of the components is roughly 0.8 instead of the 1.4 mag. heretofore thought.) These preliminary results suggest that even bright stars are not completely understood.

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